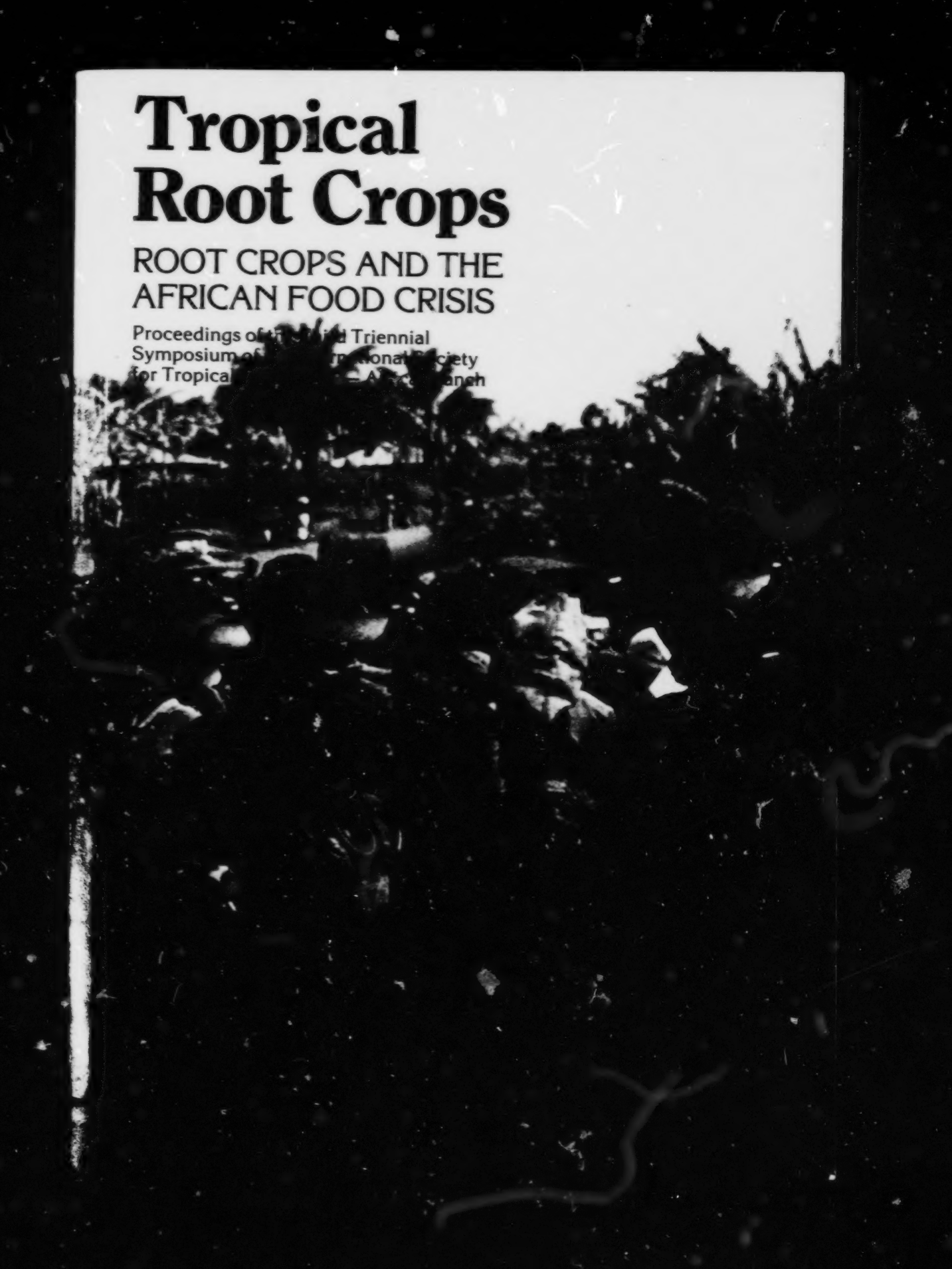
Tropical Root Crops

ROOT CROPS AND THE AFRICAN FOOD CRISIS

Proceedings of the Third Triennial Symposium of the International Society for Tropical Root Crops — African Branch



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The International Society for Tropical Root Crops — Africa Branch was created in 1978 to stimulate research, production, and utilization of root and tuber crops in Africa and the adjacent islands. The activities include encouragement of training and extension, organization of workshops and symposia, exchange of genetic materials, and facilitation of contacts between personnel working with root and tuber crops. The Society's headquarters are at the International Institute of Tropical Agriculture in Ibadan, Nigeria, but its executive council comprises eminent root and tuber researchers from national programs throughout the continent.

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TROPICAL ROOT CROPS
ROOT CROPS AND THE AFRICAN FOOD CRISIS

PROCEEDINGS OF THE THIRD TRIENNIAL SYMPOSIUM OF THE INTERNATIONAL SOCIETY FOR TROPICAL ROOT CROPS — AFRICA BRANCH HELD IN OWERRI, NIGERIA, 17–23 AUGUST 1986

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ABSTRACT

The theme of the third triennial symposium of the International Society for Tropical Root Crops — Africa Branch was "Root crops and the African food crisis." This publication contains the 64 papers, in full or abstract form, that were presented and discussed at the symposium. The root crops studied included cassava, yam, sweet potato, potato, cocoyam, and other minor root crops, and the topics of the papers included breeding and agronomy, protection, postharvest technology, and socioeconomics of production and utilization. Overall, the papers indicated that, with proven new technologies and management practices, root crops can play a major role in alleviating the African food crisis.

RÉSUMÉ

Le troisième symposium triennal de la Société internationale pour les plantes-racines tropicales — Direction Afrique, a porté sur «Les plantes à tubercules et la crise alimentaire en Afrique». Le présent ouvrage contient, en entier ou en abrégé, les 64 exposés présentés et commentés lors du symposium. Parmi les plantes à tubercules étudiées et les sujets abordés mentionnons le manioc, l'ingname, la patate douce, le taro, et autres plantes à tubercules mineures, la sélection et l'agronomie, la protection des plantes et les techniques de post-récolte, la socioéconomie de la production et de l'utilisation des plantes. Les communications ont, dans l'ensemble, souligné qu'avec de nouvelles techniques éprouvées et de bonnes méthodes de gestion les plantes à tubercules peuvent contribuer de façon importante à réduire la crise alimentaire en Afrique.

RESUMEN

El tercer simposio trienal de la Sociedad Internacional de Raíces Tropicales — Sección Africana, tuvo como tema "Los tubérculos y la crisis alimentaria en Africa". Esta publicación contiene las 64 ponencias, tanto en la versión íntegra como los resúmenes, que fueron presentadas y discutidas en dicho simposio. Se estudiaron tubérculos como la yuca, el ñame, la batata, la papa, el cocoñame y otros de menor importancia. Las ponencias versaron sobre temas como fitomejoramiento y agronomía protección de cosechas, tecnología postcosecha y aspectos socioeconómicos de la producción y utilización. En términos generales, las ponencias coincidieron en que, con nuevas tecnologías y prácticas de manejo adecuadas, los tubérculos pueden desempeñar un papel importante para mitigar la crisis alimentaria en Africa.

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FOREWORD

A significant proportion of the world's hungry people are found in the countries of sub-Saharan Africa. In 30 of the 35 countries in this region, population increases have far outstripped food production; in 5 of these countries, food production has decreased in real terms. Therefore, the attainment of self-sufficiency in food production in sub-Saharan Africa is today one of humanity's greatest challenges.

The invited and contributed papers presented at the third triennial symposium of the International Society for Tropical Root Crops — Africa Branch (ISTRC — AB) all addressed this paramount challenge and proposed various roles for the major tropical root crops in alleviating the African food crisis. This publication is the result of the deliberations of 132 participants from 11 countries. The meeting was held in Owerri, Imo State, Nigeria, 17–23 August 1986.

The five theme papers addressed the role of cassava, yam, sweet potato, cocoyam, and root crops postharvest technology in alleviating the African food crisis. A substantial number of the remaining papers report research and extension results on various aspects of cassava, yam, sweet potato, potato, and cocoyam breeding and agronomy. Other papers presented new ideas and status reports on root crops protection, postharvest technology and utilization, and the economics of production and marketing.

As a whole, the papers indicated that, with regard to root crops, the food self-sufficiency challenge could be met with a vast array of proven new technologies and management practices. Major emphasis was placed on an examination of the potentials of postharvest technology and utilization. Serious consideration was given to the socioeconomic and utilization aspects of the major root crops as a basis for agronomic and genetic research. Finally, it was proposed that the current bias and seeming neglect of root crops and their potentials could be confronted through publications, workshops, and symposia of this type. It is envisaged that the outcome of these activities will influence those national policies and priorities that affect the allocation of resources for tropical root crops research and development.

Support for the symposium and for this publication was provided by the International Development Research Centre (Ottawa, Canada), the International Foundation for Science (Stockholm, Sweden), the International Institute of Tropical Agriculture (Ibadan, Nigeria), and the Federal Government of Nigeria, through its National Root Crops Research Institute (Umudike, Nigeria).

E.R. Terry
Editor-in-Chief, ISTRC — AB

OFFICIAL ADDRESSES

MINISTERIAL ADDRESS

EMMANUEL U. EMOVON, MINISTER OF SCIENCE AND TECHNOLOGY, NIGERIA

It gives me great pleasure to address you this morning on the occasion of the formal opening of the third triennial conference and symposium of the International Society of Tropical Root Crops — Africa Branch (ISTRC — AB) being hosted by the National Root Crops Research Institute (NRCRI), Umudike, which is one of the research institutes under the aegis of my Ministry: the Federal Ministry of Science and Technology. I would like to express my sincere gratitude to the Chief of General Staff, Commodore Ebitu Ukiwe, for kindly consenting to declare the conference open. I also thank the Military Governor, Imo State, who is present with us here at this opening ceremony.

I am glad that the conference is being held in Nigeria at this time. I consider the theme of this conference, "Root crops and the African food crisis," to be appropriate because of the avowed commitment of the present administration to achieve, in the shortest time possible, self-sufficiency in food production for all Nigerians, production of raw materials for the agroallied industries, and, possibly, excess production of food for export. The presence of the Chief of General Staff at this conference, in spite of his very tight schedule, attests to this strong commitment. I believe that the conference will consider and find solutions to the numerous problems constraining increased productivity of our root and tuber crops.

Root and tuber crops — notably cassava, yam, cocoyam, sweet potato, and Irish potato — are very important crops in this country. First, as food for humans, these crops, according to Food and Agriculture Organization (FAO) estimates, provide 15% of all the food energy and 10% of all the protein in the daily diet of a typical Nigerian. Second, the demand for these crops as livestock feed and as industrial raw material for the production of alcohols and acetones, as well as starches for textiles and pharmaceutical industries, has increased tremendously over the last few years. Third, the production of, and trade in, these crops offers employment to about 60% of our rural population.

Over 3×10^6 ha of farmland are planted to these crops annually in Nigeria, yielding about 30×10^6 t of roots and tubers. In spite of this large amount of produce, there is still a serious shortfall in production because of an ever-increasing demand, the use of low-yielding varieties that are susceptible to pests and diseases, as well as the use of inefficient production and storage technologies. These and other production problems merit close attention at this conference.

This is not to play down the role of NRCRI in enhancing the productivity of our root and tuber crops. If anything, the Institute has enhanced the productivity of these crops by more than 50% over the last decade. In the early 1970s, the Institute played a major role in controlling cassava bacterial blight, and, in collaboration with the Institute for Agricultural Research and Training and the International Institute of Tropical Agriculture (IITA), both in Ibadan, NRCRI is currently working hard to control two devastating insect pests of cassava: the cassava mealybug and the green spider mite. In addition to its work on cassava pests, the Institute recently developed the minisett technique for the commercial production of seed yams. I am reliably informed that this development has significantly lowered the market price of seed yams, thereby lowering the cost of yam products. Hitherto, the cost of seed yams was a major constraint to increased yam production in Nigeria, accounting for up to 40% of the total cost of yam production. The Institute has also developed methods for the rapid multiplication of cassava.

The mandate of the Federal Ministry of Science and Technology includes the promotion and coordination of research and development activities within the country, as well as collaboration and cooperation in scientific and technological activities with international science and technology bodies. In pursuance of these objectives, my Ministry not only promotes and coordinates interaction among our national research institutions, but also encourages and fosters linkages between our research institutions and international organizations, societies, and agencies con-

cerned with agricultural research and development. Such interaction with international institutions such as IITA has proven very fruitful, e.g., the development of control measures for the cassava mealybug and green spider mite, and the productivity of other crops (e.g., maize sorghum, rice) grown in this country has been enhanced through collaboration between IITA and other national research institutes.

I see that many papers covering several aspects of root and tuber crops research and development are scheduled to be presented and discussed during this week-long conference. I hope that, through your discussions and cross-fertilization of ideas, more effective strategies for achieving increased productivity of these crops (roots and tubers) emerge. Hunger, starvation, and malnutrition have become the bane of many African nations. The yearly population growth in Africa, which is about 3%, exceeds the yearly growth of gross domestic product, which is about 1.5%. The attainment of a balance and, subsequently, a surplus of food is your responsibility. As scientists, you are challenged to turn the situation around through intensive research leading to increased food production. You cannot afford to fail!

In conclusion, let me wish you fruitful deliberations and a pleasant and safe journey home after the conference.

WELCOMING ADDRESS

L.S.O. ENE, DIRECTOR,
NATIONAL ROOT CROPS RESEARCH INSTITUTE, UMUDIKE, NIGERIA

The entire staff and student body of the National Root Crops Research Institute, Umudike, are happy and proud to host the third triennial symposium and conference of ISTRC — AB. We are grateful to the Federal Military Government of Nigeria, represented here by the Chief of General Staff, General Headquarters, Commodore Ebitu Ukiwe, for permitting this conference to be held in Nigeria and for facilitating the movement of our guests from brother African countries and elsewhere. We also thank the Military Governor of Imo State, Navy Captain Alison Madueke, for our well-being here, and for moral, physical, and financial support of this conference. NRCRI operates under the aegis of the Federal Ministry of Science and Technology and Professor E.U. Emovon, the Honourable Minister. His encouragement and financial support are gratefully acknowledged and the patronage and assistance of the Honourable Minister of Agriculture, Water Resources and Rural Development, Lt. Gen. Alani Akinrinade (retired), are highly appreciated. The support of the International Development Research Centre (IDRC), Ottawa, Canada, the International Foundation for Science (IFS), Stockholm, Sweden, IITA, Ibadan, Nigeria, and other international organizations, for both the African National Programmes and their collaboration in hosting this symposium, are acknowledged.

The presence of the Chief of General Staff, the Military Governor of Imo State, and the honourable ministers of Agriculture, Water Resources and Rural Development, and of Science and Technology indicates the emphasis the Federal Military Government has placed on agricultural research and development. It is the determination of our government to see that food is provided for all and that Nigeria becomes self-sufficient in food production in the near future, certainly by the year 2000. The third triennial symposium is already a success with the presence, the backing, and the support of these eminent citizens.

Roots and tubers are very important in the food basket and food desk of Nigerians. A typical Nigerian consumes 300 g of roots and tubers every day. This value extrapolates to an annual consumption of 13×10^6 t of roots and tubers. Current annual production estimates (millions of tonnes) for Nigeria are as follows: yam, 16.75 (75% of world production); cassava, 12.50 (fourth largest world producer); cocoyam, 0.40; Irish potato, 0.30; sweet potato, 0.25; ginger, 0.10; others, 0.20. In total, Nigeria produces 30.50×10^6 t of roots and tubers annually. It is estimated that we consume 43% of the total production, 32% is lost in the field and in storage to rodents, pests, diseases, and physiological degradation, 15% is reserved for replanting, 8% is utilized in industries, and a meager 2% is exported.

The nutritional needs of Nigerians are not met. The average per capita daily intakes of food energy (calories) and protein are below the minimum stipulated by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Energy available per caput per day is 1790 cal; FAO and WHO recommend a daily intake of 2500 cal/caput (1 cal = 4.19 J). The protein (animal and vegetable) shortage is worse: 45.5 g/caput per day is available; FAO and WHO recommend a daily minimum intake of 65.0 g/caput. Thus, the estimated supply gaps are 28.4% for carbohydrates and 30% for proteins. It will be useful and interesting during this symposium to compare values and share experiences with other African countries. Generally, these shortages lead to undernutrition and malnutrition, with a consequent impairment of health.

The challenges that we are faced with here are obvious:

- The average yields we obtain from most roots and tubers are well below the potentials of the crops.
- The losses in the field and in storage as a result of pests and diseases run into millions of tonnes and, hence, into billions of naira (1 t of roots or tubers is worth an average of NGN 120; in February 1987, 2.6 Nigerian naira [NGN] = 1 United States dollar [USD]).
- A high percentage of the yield available is used as planting material.

- Very little of available yield is used industrially (for flours, starches, sugars, glues, alcohols, acetones, etc.) to save foreign exchange or for livestock feeds to produce vital protein.
- Very little of available yield is exported.

Our research, extension, and development efforts should address these problems. This symposium offers a unique opportunity to sensitize the research and extension teams, document results obtained globally in Africa, and develop strategies of research and development for the next 3 years, that is, until the next symposium.

We hope that our various governments will continue to recognize the immense contributions that roots and tubers can make to the food requirements of their populations, to industrial and livestock production, and to export earnings. The contribution to export earnings will particularly help to stimulate production through ensuring fair prices for any amount of production. Roots and tubers usually face a low price elasticity of demand.

I thank all of you here today for your presence and your support — they are invaluable.

OPENING ADDRESS

EBITU UKIWE, CHIEF OF THE GENERAL STAFF, NIGERIA

On behalf of the Federal Government of Nigeria, I welcome all of you gathered here today from Nigeria and other countries in and outside Africa to Nigeria and to Imo State, which happens to be my home state. I understand that this is the third triennial conference and symposium of ISTRC — AB on roots and tuber crops and the second one held in Nigeria, where this branch of the international mother society founded in 1967 was launched in 1978. A conference on this diverse group of crops, which have the general characteristic of their economic parts being produced underground, at this time in Imo State is timely and relevant for several reasons.

First, Imo State is in the yam zone of West Africa, where, among food crops, the yam is king. The cultural importance of this is reflected in the annual Ahiajoku lectures, which are held in November in Owerri and are named after the yam festival, a popular traditional ritual of great antiquity throughout the yam zone of West Africa.

Second, root and tuber crops are dominant or codominant crops in the humid and subhumid areas of Nigeria. They account for 50 to over 75% of the food energy intake of the rural and, to some extent, urban populations in Nigeria and elsewhere in the yam zone.

Third, I am informed that, according to recent available statistics, Nigeria accounts for 6–7% and 22.3% of arable land under roots and tubers in the world and Africa, respectively. In fact, Nigeria accounts for about 5% of the world's and over 33.0% of Africa's production of roots and tubers as compared with less than 0.01% of the world's and less than 1% of Africa's production of cereal crops. It is obvious that roots and tubers make considerable contributions to the nutrition, income, and well-being of millions of people in Nigeria in particular and in the humid and subhumid areas of the world in general.

Fourth, at a time when the Federal Military Government of Nigeria is following the Lagos Plan of Action, in which all Organization of African Unity (OAU) countries, as signatories, are giving a high priority in various programs and strategies to attaining food self-sufficiency, roots and tubers have a vital role to play in achieving this very necessary and laudable objective. Without food self-sufficiency and self-reliance, our claim to be politically independent would be unrealistic.

Fifth, most root and tuber crops are grown in areas that are infrequently subjected to drought and can be relied upon during such calamities to contribute significantly to available food supplies. This is true even in the drier areas, where some crops, such as cassava, are fairly resistant to drought and are grown as famine-relief crops.

Finally, the Federal Military Government recently decided to ban wheat imports as of next year. This demands that a greater priority be given to root and tuber crops, which can more reliably contribute to a solution to the African food crisis — currently of worldwide concern.

In the agenda of papers to be presented, there are topics on the improvement, production, physiology, protection, harvesting, storage, postharvest activities, processing, and utilization of such crops as yams, cassava, sweet potatoes, cocoyams, ginger, and Irish potatoes. Various aspects of these topics are being addressed by our research institutions, especially NRCRI at Umudike, the Federal Institute of Industrial Research at Oshodi, the Project Development Institute (PRODA) at Enugu, the Nigerian Stored Products Institute, and other agricultural research institutes and faculties of agriculture in our universities. I am gratified to note that this years' symposium is being sponsored by NRCRI and I am confident that the Minister of Science and Technology, Professor E.U. Emovon, who is here with us today, will elaborate on policy issues and priorities of the Federal Government in research on these crops and progress being made. The Minister of Agriculture, Water Resources and Rural Development, Lt. Gen. A.I. Akinrinade (retired), will inform you not only about programs and policies aimed at boosting agricultural production but also about recent measures aimed at realizing the full potentials of

these crops both in satisfying our demand for food and industrial raw materials and, possibly, for export. Our scientists will present papers dealing with efforts being made in research and problems still to be solved.

Our research institutes are actively collaborating with international agricultural research centres, such as IITA, and such collaboration has been quite beneficial to Nigeria in the improvement and production of root and tuber crops and in combating recent ravages of the cassava crop by cassava bacterial blight, cassava mealybug, and green spider mite. This collaboration has also been equally rewarding in the recent advances made in the yam minisett propagation technique that has been pioneered by NRCRI and further improved upon through contributions from IITA and other institutions. This symposium provides a rare opportunity for direct dialogue and exchange of information among African scientists and we hope that it will lead to some collaborative linkages among individuals and institutions in Nigeria and other African countries.

I take this opportunity to remind you that the Federal Military Government has placed a ban on rice and wheat imports, which account for a large proportion of the up to NGN 2 billion that was spent annually on food imports into Nigeria to satisfy escalating demands. One major reason for our high food import bill for cereal grains is the increasing demand for convenience foods, which are less tedious to prepare. In this regard, food grains have obvious advantages over roots and tubers. Those of you who visit or live in Europe or the United States should notice the importance of Irish potatoes as chips or French fries in the fast-food business. This requires that Nigeria develop capabilities in food processing and crop utilization. The extent to which we can develop a range of convenience foods from our roots and tubers, in addition to processing them into more convenience forms similar to our traditional food preparations, will determine the degree to which we can save foreign exchange through import substitution.

There are people who maintain that it is not reasonable to ban wheat importation because we cannot do away with bread. There are others who maintain that cassava, which could be used in bread making, contains a toxic substance, hydrogen cyanide, and, therefore, is dangerous to use in bread making. We are aware, however, that in recent years food scientists have been able to produce a range of products that are often indistinguishable from traditional preferred products in different parts of the world. Through interaction with nutritionists, they have been able to develop technologies for eliminating antinutritional or toxic factors in foods and, with the assistance of chemists, procedures have been developed for quality control to ensure high levels of food safety. We are convinced that, even if wheat cannot be completely eliminated from bread, it is quite possible that Nigerian scientists will be able to determine the minimum amount of wheat that would be necessary for use in composite flours that will be used to produce bread with the textural, rheological, and nutritional characteristics that will make a "Nigerian bread meet the standards that are both locally and internationally acceptable." With regard to the toxic factors in cassava, I am reliably informed that there are effective methods of lowering the cyanide content to a level that is not dangerous to human beings. Government has the confidence that if Nigerian scientists in particular and African scientists in general accept the challenge, we should be able to produce a range of convenience foods and bread substitutes that will meet the demands of urbanization, increasing affluence, and other pressures of modernization. The socioeconomic changes leading to our increasing acquisition of foreign tastes that rely on consumption of imported foods, which our economy cannot support, must be tackled or halted by Nigerian or African scientists. Food shortages cannot effectively be solved by reliance on those countries who prosper by our increasing reliance on the foodstuffs and products they export.

Another challenge that faces the scientist is that of conducting research of sufficient scope to assist our standards organization to effectively guide government not only in the formulation of food and drug laws and legislation but also in developing techniques for monitoring and ensuring quality control of processed foods. This is important because without mechanisms for law enforcement the laws and regulations on food safety are useless and exist only on paper. The Federal Military Government relies on scientists to develop suitable methods of processing cassava for production of flour that is safe for human consumption. However, unless we have the specifications for food processors to follow in commerical production of cassava flour, this is not enough. With such specifications, it will be possible to set up a certification machinery that will be used in certifying products and licensing processors who specialize in commercial cassava flour production.

Production of processed foods of all kinds needed to ensure availability of food to meet demand during all seasons of the year is the responsibility of producers, processors, marketing specialists, and scientists in different disciplines. It is, of course, the responsibility of the federal government to formulate and execute policies and support research and development programs in various institutions that conduct innovative research for finding solutions to our current problems. In all your deliberations and exchange of ideas about future research and development

activities, I feel strongly that you give due consideration to finding ways of improving and increasing the production of underutilized or neglected root and tuber crops.

Of course, I am convinced many of you will complain that resources available for research, especially with respect to necessary funding, are not being provided or are otherwise inadequate because of serious budgetary shortfalls caused by the economic squeeze that Nigeria is experiencing. The Ministry of Science and Technology is currently engaged in reorganizing our research institutes and finding ways of ensuring better funding of research and development. Under the unfavourable economic conditions in Nigeria and elsewhere, it is also the duty of our scientists to learn to "cut their coats according to their sizes." While it is recognized that research and development is expensive and should be adequately funded, there is no doubt that sometimes considerable amounts of funds have been spent on massive, ill-conceived buildings that cannot be completed or equipped because no money is available. Similarly, sophisticated equipment at various locations remains in a state of disrepair because of the unavailability of skilled labour and appropriate parts. I am informed that some of the objectives for which such equipment and facilities were requested could have been accomplished equally well with simpler, less costly, and in no way inferior facilities and equipment. I do not feel that enough improvisation and adaptation of equipment for a range of possible uses have received the attention and priority they require where resources are limited.

I have tried in this brief address to emphasize that your society is doing the right thing by encouraging the improvement, production, processing, and utilization of roots and tubers. Nigeria and other African countries must develop capabilities to plan and execute research and development activities needed to realize the full potential of roots and tubers in nutrition, in the production of raw materials for industry, in contributing to rising incomes of our small farmers, and in economic development.

The Federal Military Government is formulating policies and launching programs that will boost food production in general and roots and tuber crops in particular. Nigerian scientists and, in fact, those of you from other African countries have a crucial role to play in this regard. Government is ready to work hand-in-hand with scientists in finding solutions to the African food crisis, in which root and tuber crops play a significant role.

On behalf of the federal government of Nigeria, I again welcome all of you and declare this important conference and symposium open. I wish all of you successful deliberations and exchange of information and experiences. I hope that our visitors will be able to acquaint themselves with what Nigerians working on these crops are trying to accomplish. We look forward to your suggestions and advice and wish all of you a safe return home at the end of the symposium.

KEYNOTE ADDRESS: ROOTS AND TUBERS IN THE AFRICAN FOOD CRISIS

BEDE N. OKIGBO, INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE, IBADAN, NIGERIA

The African food crisis emanated from the inability of most countries of sub-Saharan Africa during the past 15 years to achieve satisfactory levels of domestic food production. This failure was due to inadequate foreign exchange, drought in the early 1970s and 1980s, and rapid population growth (3% annually, compared with 1–2% for food supply). Despite a steady increase in total food production by these countries, per capita food production has been declining by about 1% annually over the last 15 years. Many African countries increasingly rely on imports of expensive cereal grains or food aid to satisfy demand and the widening gap between per capita food production and requirements.

All recent reports express concern about the gravity of the worsening food crisis in sub-Saharan Africa and that these problems relate to food supplies and the overall development of the continent; partly arise from much deeper issues such as drought, widespread damage by plant diseases and pests, and livestock diseases; are worsened by annual population growth exceeding food production (FAO 1984); and relate to the fact that food imports, especially cereals, have been increasing by over 10% annually since 1970. In 1983, food aid reached 2–3 $\times$ 10^6 t. Brown (1986) observed that food deficits in Africa are adding to trade deficits throughout the continent, and this is associated with ecological deficits that occur when demands on the natural ecosystem exceed the carrying capacity. This imbalance is a result of land clearing for agriculture, overgrazing, firewood gathering, and harvesting by lumber and paper industries. As of the mid-1980s, every country in Africa is losing tree cover.

One reason for Africa's inability to achieve dramatic advances in grain production as in Asia is that, whereas Asian agriculture is dominated by wetland cultivation (particularly rice), Africa, in contrast, depends on several staples — corn, wheat, sorghum, millet, barley, and rice among cereals, and cassava and yams — and a highly heterogenous collection of farming systems. Based on this background, this paper discusses the diversity, roles, and potential of roots and tubers in providing solutions to the African food crisis and measures to be taken to realize their full potential.

ROOT AND TUBER CROPS IN AFRICA

Roots and tuber crops are edible, fleshy (high water content), underground storage organs rich in starch, sugar, or both, and with varying amounts of other nutrients (Table 1). As a matter of practice, ginger rhizomes, Irish potato and yam tubers, cocoyam corms, and onion bulbs are not usually considered as root and tuber staples. Strictly, carrots and beets are as much root crops as are cassava and sweet potatoes.

DIVERSITY OF ROOTS AND TUBER CROPS

Roots and tuber crops belong to over 20 diverse families in different parts of the world. (Purseglove 1969, 1975; Schery 1972; Kay 1973; Brouk 1975; Janick 1981). Species of major economic and nutritional importance are Irish potatoes (*Solanum tuberosum*, family Solanaceae), cassava or manioc (*Manihot esculenta*, family Euphorbiaceae), sweet potatoes (*Ipomoea batatas*, family Convolvulaceae), yams (*Dioscorea* spp., family Dioscoreaceae), beets (*Beta vulgaris*, family Chenopodiaceae), cocoyams (*Colocacia* and *Xanthosoma* spp., family Araceae), carrots (*Daucus carota*, family Umbelliferae), and ginger (*Zingiber officinale*, family Zingiberaceae).

STATUS OF DOMESTICATION AND ORIGIN

The root and tuber crops of the world may be fully domesticated major staples (e.g., Irish potatoes, sweet potatoes, cassava, cocoyams, and yams); semi-wild, minor, or recently domesticated crops (e.g., African and Asian yambeans (*Parchyrrhizus erosus*

Table 1. Composition of various yam tubers, portions of cocoyam, and edible leaves of some major roots and tubers.

Component	Yam tubers[a]					Cocoyam[b]			Edible leaves[c]		
	1	2	3	4	5	C	L	P	C	T	SP
Moisture (%)	60–70	70	80	70–80	80	77.5	79.6	93.8	73.6	90.5	87.5
Protein (%)	1.1–2.0	1.1–2.8	1.0	1.3–1.9	2.8	2.5	4.4	0.2	—	—	—
Fat (%)	0.1	0.1–1.3	0.1	0.1–1.3	0.3	0.2	1.8	0.2	0.7	11.7	0.8
Carbohydrate (%)	—	—	—	—	—	19.1	12.2	4.6	—	—	—
Starch (%)	—	28	—	25	—	—	—	—	3.5	—	8.0
Sugars (%)	—	0.5	—	0.6	—	—	—	—	3.3	—	4.0
Fibre (%)	0.4–0.8	0.6–1.4	0.4	0.2–1.5	0.3	0.4	3.4	0.6	—	—	1.4
Ash (%)	0.7–2.6	0.7–2.1	0.5	0.5–1.2	0.7	0.8	2.0	1.2	1.7	12.2	10–11.4
P (mg/100 g)	135	168	89	181	211	64	28	23	98	360	67
Ca (mg/100 g)	23.3	18.1	14.3	30.4	42.9	32	268	57	187	6	81–98
Fe[d]	15	11.6	18.6	12.1	26.4	0.8	4.5	1.4	3.0	0.7	10.4
Na (mg/100 g)	—	—	—	—	—	7	1.1	5	—	—	—
K (mg/100 g)	—	—	—	—	—	514	12.37	367	—	—	—
Mg (mg/100 g)	51.9	65.7	44.4	74.8	75.0	—	—	—	—	—	—
Vitamin A (mg/100 g)	0.8	—	—	—	—	Tr	20385	335	9.7	0.05	56–81
Vitamin B_1 (mg/100 g)	—	0.09	—	0.08	—	0.18	0.10	0.10	0.04	0.05	0.06
Vitamin B_2 (mg/100g)	—	0.03	—	0.02	—	0.04	0.33	0.02	0.02	0.08	0.17–0.21
Vitamin C (mg/100 g)	6–12	5–8	—	—	—	10	1.42	8	248	10	25–38
Niacin (mg/100 g)	—	—	—	—	—	0.9	2.0	0.2	0.6	—	0.07–0.9
Oxalic acid (mg/100 g)	—	—	—	—	—	—	—	—	109	—	—
Food energy (cal)[e]	—	—	—	—	—	85	69	19	—	—	—

[a] Most of the yam tuber data is from Onwueme (1978); values for P, Ca, Fe, and Mg are from Bell (1983). Species: 1, *Dioscorea rotundata*; 2, *D. alata*; 3, *D. cayenensis*; 4, *D. esculenta*; 5, *D. dumetorum*.

[b] C, corms; L, leaves; P, petioles. Edible portion (%): C, 81; L, 55; P, 84. Tr, trace.

[c] C, cassava; T, tannia; SP, sweet potato. Vitamin A values represent carotene (1.4) or vitamin A.

[d] Units: yam tubers, ppm; cocoyam and edible leaves, mg/100 g.

[e] 1 cal = 4.19 J.

and *Sphenostylis stenocarpa*) chufa (*Cyperus esculentus*), bitter yams (*Dioscorea dumetorum*), and bulbil-bearing or aerial yams (*Dioscorea bulbifera*)); or wild species, which are often consumed in times of famine and food scarcity (e.g., elephant yams (*Amorphophallus* spp.), kudzu (*Pueraria lobata*), lotus nut (*Nelumbo nucifera*), wild yams (*Dioscorea* spp.), and false yams (*Icacina senegalensis*)).

Exotic root and tuber crops grown in Africa include sweet potatoes, Irish potatoes, cassava, cocoyams, and carrots (Table 2). Only cassava, however, has achieved the status of a major staple in Africa. The sweet potato is important in Rwanda and Burundi, whereas cocoyams are locally important in southern Cameroon and southeastern Nigeria. Of the root and tuber crops of African origin listed in Table 3, only the African yams (*Dioscorea* spp.) have become major staples of local or regional importance in the yam zone of West Africa, stretching from Cameroon to the Bandama River in Côte d'Ivoire, with a minor break in the Benin (Dahomey) gap, and in parts of the West Indies. The labiates, *Plectranthus* and *Solenostemum* spp., are of minor, local importance in parts of the Middle Belt of Nigeria (Plateau, Benue, and Bauchi states) and in Central and Southern Africa.

Importance and Uses of Roots and Tubers

Roots and tubers contribute about 10% of human sustenance as compared with 60% from cereal grains and 10% from fruits, nuts, and vegetables (Janick 1981). According to Paulino and Yeung (1981), major staples and food crops produced in sub-Saharan Africa consist of about 53% cereals, 31% roots and tubers, 6% grain legumes, and 5% each of groundnuts, and plantains and bananas. In coastal or humid tropical areas of Ghana, Nigeria, Côte d'Ivoire, Cameroon, and Zaire, roots and tubers account for over 50% of the food energy intake. Irish potatoes, sweet potatoes, cassava, and sugar beets are among the 15 major crops of the world that contribute over 75% of the world per capita daily calorie consumption and over 60% of the per capita daily protein supply.

Roots and tuber crops also yield industrial and pharmaceutical products and are becoming more commercially important (B.N. Okigbo, unpublished).[1] Overall uses of most root and tuber

[1] Okigbo, B.N. Roots and tuber crops in human nutrition. Unpublished draft report. 32 pp.

Table 2. Exotic root and tuber crops grown in tropical Africa.

Latin name	Common name	Origin	Status
Arracacha xanthorrhiza	Arracacha	South America	
Beta vulgaris[a]	Garden beets	Mediterranean region and Europe	
Canna edulis	Queensland arrow root		Limited local importance
Colocasia esculenta	Dasheen, edo	Southeast Asia	Minor importance
Curcuma longa	Tumeric	Southeast Asia (India)	
Cyperus esculentus	Chufa	Mediterranean	
Daucus carota	Carrot	Mediterranean	Minor importance
Dioscorea alata	Water yam	Southeast Asia	Minor importance
Dioscorea esculenta	Chinese yam	Southeast Asia	Minor importance
Helianthus tuberosus	Jerusalem artichoke	North America	
Ipomoea batatas	Sweet potato	Southern Central America	Minor importance
Manihot esculenta	Cassava, manioc	Central and South America	Minor importance
Raphanus sativus	Radish	Europe and Asia	
Solanum tuberosum[a]	Irish potato	South America	Minor importance
Xanthosoma saggitifolium	Tannia	Tropical America	Minor importance

Source: Kay (1973).
[a] Found in the highlands.

Table 3. Indigenous root and tuber crops of Africa.

Latin name	Common name	Distribution	Status[a]
Amorphophallus spp.	Elephant yam	Humid and subhumid tropical Africa — wild	
Anchomanes difformis	—	Tropical Africa — wild	
Cyrtosperma senegalense	—	Tropical Africa — wild	
Dioscorea bulbifera	Aerial yam	Tropical Africa — cultivated and wild	C
Dioscorea cayenensis	Yellow Guinea yam	Humid tropical areas of West and Central Africa	B
Dioscorea dumetorum	Threeleaved yam	Tropical Africa, cultivated in eastern Nigeria	
Dioscorea praehensilis	—		
Dioscorea rotundata	White Guinea yam	Humid and subhumid areas of West Africa — cultivated	A
Icacina senegalensis	False yam	West and Central Africa — wild	
Plectranthus esculentus	Risga	Tropical Africa — cultivated	C
Solenostemum rotundifolius	Hausa potato	Tropical Africa — cultivated	C
Sphenostylis stenocarpa	African yambean	West and Central Africa — cultivated	
Stylochiton warneckei	—	Tropical Africa — wild	

Source: Kay (1973), Okigbo (1983).
[a] A, major regional or local importance in West Africa; B, limited local importance in West Africa; C, minor local importance in parts of West Africa.

crops grown in Africa are presented in Table 4. Some root and tuber crops, such as ginger and carrots, are used to improve the flavour of less tasty foods. Cassava, potatoes, and yams have essentially formed the basis of civilizations, socioeconomic organizations, and religious rituals in Africa, Oceania, and Latin America. Most of these crops, which were domesticated over two millenia ago, have since spread worldwide (B.N. Okigbo, unpublished, see footnote 1).

THE AFRICAN FOOD CRISIS

Of the world's major food commodities, in 1984, Africa accounted for 2.5% of the cereal grains, 14.9% of the roots and tubers, 10.5% of the grain legumes, 3.9% of the vegetables, 8.9% of the fruits, 7.4% of the nuts, 4.0% of the sugar, 3.5% of the meat, 1.7% of the milk, and 2.6% of the eggs (FAO 1985). Because Africa accounted for about 11.3% of

Table 4. Main food preparations and uses of root and tuber crops grown in tropical Africa.

Crop	Food preparations	Other uses and remarks
Cassava	Fufu; tapioca and farinha, flour (lafun); gari; boiled cassava (sweet varieties); bread and composite flour; leaves used as vegetables; flakes and chips; biscuits	Starch for industrial use; chips and pellets used for livestock feed; alcohol
Yams	Boiled yam; fried and roasted yam; fufu or pounded yam; chips and flakes; cakes; mashed yam; yam flour	Livestock feed; contains sapegonins as diosgenin used in corticosteroid drugs and contraceptive pills (African yams not rich in these); alcohol also manufactured (not attractive)
Sweet potatoes	Chips; boiled tubers and canned, fried, and roasted, or baked, frozen, chilled, and made into pruic; leaves used as green vegetables	Used for animal feed; starch (not economical), alcohol; syrup
Cocoyams	Tuber boiled, roasted, and eaten; tuber boiled and eaten; leaves and flowers eaten boiled	Leaves yield fibre; starch
Irish potatoes	Starchy staple eaten boiled, roasted, baked, fried, mashed, processed into canned whole potatoes, frozen French fries, chips, crisps, dehydrated flakes, powder, granules, potato salad, etc.; flour regarded as oldest commercially processed product of the potato and is used in baking certain types of bread, pastries, cakes, biscuits, etc.; sprouts used as vegetables	Animal feed as fresh fodder for cattle and sheep, silage, or dried meal; industrial source of starch in USA, Denmark, and Netherlands; starch used for food, paper, and textile industry and manufacture of adhesives, modified starch products such as amylopectin, and preparation of glucose and dextrins; alcohol and potato spirits produced through pulping and fermentation in some European countries; pulp from starch manufacture fed to livestock and effluently used as source of high-grade starch for production of butane or acetone; potato juices from manufacture source of high-grade protein. Citric acid by-product of starch manufacture or from hydrolysis of the starch and fermentation of sugars
Hausa potato	Cooked and eaten as source of carbohydrate as is done with yams and potato; may be cooked as curry and eaten with rice or boiled, baked and fried into chips	Sometimes used as drug plant for treatment of dysentery and eye disorder
Risga	Tubers eaten raw or boiled; sometimes pickled	Claimed to give higher root yield than any other labiate
African yambean	Storage roots eaten after boiling	Cultivated more often for its edible seeds; roots have 6–14% protein
Chufa	Corms eaten raw or baked as a vegetable; roasted and eaten or grated and used for ice cream, sherbets, and milky beverage norchesta in Spam	Used in animal feed and in confectionary as substitute for almonds; ground corms used as substitute or adulterant for coffee and cocoa; minor products include oil similar to olive used for soap; also yields starch, flour, alcohol, and paper from leaves

(*continued*)

Table 4. Concluded.

Crop	Food preparations	Other uses and remarks
Carrot	Eaten raw or boiled and sometimes pickled; raw carrot eaten grated with the juice extract; used for flavouring of soups and sauces	Contains large amount of carotene, hence used as colouring substance in foods such as butter; also used for stock feed
Jerusalem artichoke	Eaten boiled, fried, or in soups and stews	Contains inulin instead of starch and used for manufacture of flour and commercial source of fructose for diabetics and the preparation of 5-hydroxymethyl furfural; source of industrial alcohol for preparation of beer-like alcoholic beverage; stalks on treatment with soda–chlorine process yields 20% pulp suitable for paper making; tops fed to sheep and goats

the world's population of 4.7 billion in 1984, it should, in general, average about 11–12% of each of the above commodities to ensure food self-sufficiency assuming, of course, that the consumption patterns, requirements of various commodities, preferences, and availability were similar or the same in different parts of Africa in particular and the world in general. The proportion (27.8%) of total arable land area under roots and tubers that is in Africa and the fraction of roots and tubers from Africa (15.4% of total world production) exceeded those of any other major food group in 1984 (Table 5). For example, Africa accounted for only 9.7% of the world's arable land area under cereals and 3.5% of the world's cereal production in 1984. Of the major geographical regions of the world, Africa was second only to Asia in the area of land under roots and tubers. This amounted to 32.5% of the total land area under these food commodities as compared with 41.7% for Asia in 1984 (Table 6). Although Africa accounted for 32.5% of the area of land under roots and tubers, it was responsible for only 18% of the total world production in 1984 (Table 5). This discrepancy is due to the low yields of these crops in Africa (55.9% of the world's average), as compared with 115% for Asia and 160% for Europe (Table 6).

Food Production in Food-Deficit Countries

Food production in low-income, food-deficit countries of sub-Saharan Africa increased slightly from 1984/85 to 1985/86 with a less than forecasted cereal import, although food aid (e.g., cereal) was highest in 1984/85 at 11×10^6 t or 23% of imports during 1981–1986. During 1984/85 and 1985/86, daily prices of some major agricultural exports decreased: coffee, 5.3%; cocoa, 6.5%; sugar, 21.7%; tea, 42.5%; jute, 15.9%. This situation confirms that most African countries are experiencing food deficits that are being met by increasing cereal imports or food aid at a time in which they are experiencing an unfavourable balance of payments, heavy debt burdens, and unstable prices of agricultural export commodities, which are the main sources of foreign exchange needed to pay for the cereal imports. It is on the basis of these observations that the production and consumption of roots and tubers and strategies

Table 5. Total area and production of the major food crops in Africa and the world in 1984.

Commodity	Area (ha $\times 10^6$)		Production (t $\times 10^6$)	
	World	Africa	World	Africa
Roots and tubers	46.8	13.0 (27.8)[a]	593.2	91.6 (15.4)
Cereal grains	730.0	70.9 (9.7)	1801.7	63.1 (3.5)
Grain legumes	67.8	12.6 (18.6)	47.9	5.7 (11.9)
Vegetables and melons	386.8	26.2 (6.8)	3.9	0.3 (7.7)

Source: FAO (1985).

[a] Values in parentheses represent African area or production as a percentage of the world value.

Table 6. Total area, production, and average yields of roots and tubers in the world and the world six major geographical regions.

Region	Area (ha × 10^6)	Production (t × 10^6)	Average yield (t/ha)
Africa	13.0 (32.5)[a]	91.6 (18.0)	7.1 (55.9)
Asia	16.7 (41.7)	243.5 (48.0)	14.6 (115.0)
Europe	5.3 (13.3)	107.3 (21.1)	20.3 (160.0)
North and Central America	1.2 (3.0)	23.4 (4.6)	18.9 (144.0)
South America	3.5 (8.7)	39.3 (7.7)	11.2 (88.2)
Oceania	0.3 (0.8)	2.8 (0.6)	10.3 (81.2)
World	40.0 (100.0)	507.9 (100.0)	12.7 (100.0)

Source: FAO (1985).
[a] Values in parentheses are percentages of world values.

for realizing the full potential of roots and tubers in finding solutions to Africa's food crisis are discussed.

Status of Root and Tuber Production in Africa

Cassava is grown in humid, subhumid, and, to a lesser extent, savanna areas. It is adapted to soils of low fertility, is relatively resistant to drought, and is relatively immune to damage by locusts, which are again threatening large areas of Africa.

Africa has 7.48 × 10^6 ha under cassava, accounting for 52.9% of the world's area under this crop in 1984 (Table 7). About 51 × 10^6 t of cassava is produced annually in Africa, accounting for 39.5% of the total world production (Table 8). Cassava production has been increasing at an annual rate of 1.7% (0.6% in yield and 2.3% in production, with a per capita annual rate of −0.8%) as compared with per caput annual production growth rates of −1.1% for yams, 0.3% for sweet potatoes, −1.2% for plantains, and −1.5% for cereals (FAO 1986b). Zaire and Nigeria are leading producers, accounting for 15 and 11% of the world's cassava production in 1984, respectively.

Yams (*Dioscorea* spp.)

The countries of sub-Saharan Africa account for over 95% of the world's land area under yams and are responsible for 95.8% of the world's yam production, (Tables 7 and 8). Yam production is decreasing at an annual rate of 1.1%. Nigeria alone accounts for over 72% of the world's yam production. Similarly, West Africa, including Cameroon, accounts for over 90% of the world's yam production.

Sweet Potato (*Ipomoea batatas*)

Sweet potato is currently a minor root and tuber crop in tropical Africa despite its high potential. Africa accounted for over 4.4% of the world's sweet potato production in 1984 (Table 8). Burundi, Rwanda, and Zaire accounted for over 42% of

Table 7. Total area (ha × 10^3) devoted to the cultivation of various root and tuber crops in different geographical regions in 1984.

Region	Cassava	Yams	Sweet potatoes	Cocoyams	Irish potatoes	Carrots
Africa	7480 (52.9)[a]	23.95 (95.1)	841 (10.9)	92.6 (80.3)	660 (3.3)	32 (5.9)
West Africa[b]	2500 (33.8)	15.50 (61.2)	139 (16.5)	50.9 (54.9)	—	—
Asia	4170 (29.5)	0.16 (0.6)	6390 (82.6)	17.9 (15.5)	5810 (28.6)	160 (24.5)
USSR[c]	—	—	—	—	6830 (33.5)	140 (25.8)
Europe	0	0	13 (0.2)	0	5280 (26.0)	129 (23.8)
North and Central America	170 (1.2)	0.49 (1.9)	217 (2.8)	0.2 (0.2)	750 (3.7)	48 (8.9)
South America	2310 (16.3)	0.40 (1.6)	162 (2.1)		930 (4.6)	27 (5.0)
Oceania	20 (0.1)	0.18 (0.7)	116 (1.4)	4.6 (4.0)	50 (0.3)	5 (0.9)
World	14150 (100.0)	25.18 (100.0)	7738 (100.0)	115.3 (100.0)	20300 (100.0)	542 (100.0)

Source: FAO (1985).
[a] Values in parentheses (except West Africa) represent percentages of world values.
[b] Values in parentheses for West Africa represent percentages of African values. For yams, West African values represent Nigeria only.
[c] For Irish potatoes and carrots, Asia and the USSR are considered separately.

Table 8. Production (t × 10^6) of various root and tuber crops in different geographical regions in 1984.

	Cassava	Yams	Sweet potatoes	Cocoyams	Irish potatoes	Carrots
Africa	51.0 (39.5)[a]	24.4 (95.8)	5.1 (4.4)	3.4 (58.9)	5.8 (1.9)	413 (3.4)
West Africa[b]	17.8 (34.9)	18.5 (72.6)	0.8 (15.2)	2.6 (76.8)	—	—
Asia	50.0 (38.8)	0.2 (0.7)	108.6 (92.6)	2.0 (35.1)	82.1 (26.3)	3162 (26.1)
USSR[c]	—	—	—	—	85.3 (27.3)	2600 (21.4)
Europe	0	0	0.1 (0.1)	0	107.1 (34.3)	3885 (32.0)
North and Central America	0.9 (0.7)	0.3 (1.2)	1.5 (1.2)	0.02 (0.4)	20.4 (6.5)	1409 (11.6)
South America	26.9 (20.8)	0.3 (1.3)	1.4 (1.2)	0.01 (0.2)	10.4 (3.3)	519 (4.3)
Oceania	0.2 (0.2)	0.3 (1.0)	0.6 (0.5)	0.3 (5.6)	1.1 (0.4)	141 (1.2)
World	129.0 (100.0)	25.5 (100.0)	117.3 (100.0)	5.7 (100.0)	312.2 (100.0)	12126 (100.0)

Source: FAO (1985)

[a]Values in parentheses (except West Africa) represent percentages of world values.

[b]Values in parentheses for West Africa represent percentages of African values. For yams, West African values represent Nigeria only.

[c]For Irish potatoes and carrots, Asia and the USSR are considered separately.

Africa's sweet potato production in 1984; West Africa accounted for 15.2%. Growth rates in sweet potato have been reported to amount to 2.5% in area, 0.9% in yield, 3.4% in production, and 0.3% in per caput, per annum production from 1969/71 to 1981/83 (FAO 1986b). Therefore, it is the only root and tuber crop with a positive per caput annual rate of increase in production in sub-Saharan Africa.

Cocoyams (*Colocasia* and *Xanthosoma* spp.)

Cocoyams are of local importance in certain parts of the humid and subhumid tropics, and Africa accounted for 80.3% of the world's area under the crop in 1984 and 58.8% of the world's production (Tables 7 and 8). Second to Africa is Asia, which accounted for 15.5% of the world's area and 35.2% of the world's production in 1984; West Africa accounted for 86.1% of African cocoyam production in 1984 (Tables 7 and 8).

Irish Potato (*Solanum tuberosum*)

Irish potato is a crop of the highland tropics. In 1984, Africa accounted for 66 000 ha or 3.25% of the world's area under this crop and 5.8 × 10^6 t or 1.8% of world production (Tables 7 and 8). Most of Africa's production of this crop is in North Africa (Egypt, Algeria, and Morocco), Southern Africa, and East Africa.

Carrot (*Daucus carota*)

Carrots are a subtropical root crop that are usually grown as a vegetable or a minor subsidiary crop rather than as a major staple. Africa accounted only for 32 000 ha and 413 000 t of carrot production, which, in 1984, amounted to 5.9 and 3.4% of the world area under carrot and world carrot production, respectively (Tables 7 and 8).

Consumption of Roots and Tubers

The countries of sub-Saharan Africa have been grouped on the basis of their consumption patterns (FAO 1986b).

- Group I: the Central African Republic, the Congo, Mozambique, and Zaire. In these countries, cassava is dominant and accounts for over 50% of food intake.
- Group II: Angola, Benin, Burundi, Cameroon, the Comoros, Côte d'Ivoire, Equatorial Guinea, Gabon, Ghana, Nigeria, Rwanda, Tanzania, Togo, and Uganda. These countries have diverse consumption patterns involving cassava, yams, cereals, sweet potatoes, plantains and starchy bananas, and cocoyams.
- Group III: Botswana, Burkina Faso, Cape Verde, Chad, Ethiopia, Gambia, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Mauritius, Namibia, Niger, Réunion, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Swaziland, Zambia, and Zimbabwe. In these countries, cereals are dominant and roots and tubers are secondary.

Details of contributions of different food commodities to the per caput consumption of staple foods are shown in Table 9. Very little trade occurs in roots and tubers as compared with cereals (FAO 1986a,b). Thus, consumption patterns reflect production patterns (Table 10). Per capita consumption of roots and tubers and their contribution to the caloric intake is highest in Central Africa, followed

Table 9. Levels of per caput consumption of staple foods is sub-Saharan Africa, 1981–83.

	Group I		Group II		Group III		Total	
	kg/head	%[a]	kg/head	%	kg/head	%	kg/head	%
Roots								
Cassava	407.4	70	123.0	22	21.3	4	117.8	24
Yams	6.6	1	72.4	14	3.5	1	36.8	7
Sweet potatoes	6.6	2	20.3	3	5.0	1	12.5	2
Others	6.6	1	19.2	4	13.3	3	15.3	2
Total	427.2	74	234.9	43	43.1	9	182.4	35
Plantains	26.2	4	39.1	6	2.0	—	22.7	4
Total roots and plantains	453.4	78	274.0	49	45.1	9	205.1	39
Cereals	39.7	22	83.8	51	134.1	91	98.3	61

Source: FAO (1986b).
[a]In calorie equivalents.

Table 10. Per capita consumption (kg/year) of cassava and other roots and tubers and their per capita calorie contribution per day to the human diet in sub-Saharan Africa, 1975–84.

	Roots and tubers		Cassava		
Subregion	Calorie contribution[a]	Consumption	Calorie contribution[a]	Consumption	Cassava proportion[b]
Sahel	83.3	27.6	55.2	18.3	66
West Africa	594.3	196.8	338.6	112.1	57
Central Africa	1261.0	417.5	1049.8	347.6	83
East Africa	433.9	143.7	237.8	78.7	55
Southern Africa	375.8	124.0	317.3	105.0	85

Source: Gebremeskel (1986).
[a]1 cal = 4.19 J.
[b]Proportion (%) of cassava in total root and tuber consumption.

Table 11. Changes (%) in per caput consumption of staple foods in sub-Saharan Africa from 1969/71 to 1981/83.

Staple	Group I	Group II	Group III
Cassava	−4.4	−6.3	−6.4
Yams	−28.7	−9.4	−19.0
Sweet potatoes	−18.2	27.0	−4.4
Total roots	−4.9	−7.0	−1.2
Plantains	−12.9	13.2	−3.4
Total cereals	−0.1	6.3	−3.4

Source: FAO (1986b).

Table 12. Forecasted production, utilization, and deficit of root and tuber crops in 1995.

Crop	Production (t × 10^6)	Total utilization (t × 10^6)	Deficit (t × 10^6)
Cassava	64	75	11
Yams	29	34	5
Sweet potatoes	8	8	0
Others	9	12	3
Total	110	129	19

Source: FAO (1986b).

by West Africa, and cassava dependency is highest in these same regions (Table 10). Within the last decade, there has been a shift away from roots and tubers toward cereals in areas where these staples and plantains and starchy bananas are usually prominent (Table 11). In all groups, the largest shift is in yam consumption; in group II the largest shift is toward sweet potato and in group III the largest shift is toward plantains. This is partly due to rapid rates of urbanization and the demand for convenience foods rather than strictly the usual negative income elasticities (FAO 1986b). There is, therefore, a need to take specific measures to enhance the utilization of roots and tubers through increased production and improved processing. FAO (1986b) has forecast that, based on trends observed from 1966 to 1981 in these crops, by 1995, annual production will reach 23 × 10^6 t as compared with a demand of 42 × 10^6 t, amounting to a deficit of 19 × 10^6 t or 5 × 10^6 t cereal equivalent (Table 12).

Table 13. Average yields (t/ha) of roots and tubers observed in major geographical regions of the world in 1984.

Crop	Africa	Asia	South America	Oceania
Cassava	6.82 (74.8)[a]	11.99 (131.5)	11.62 (127.5)	10.69 (117.2)
Yams	10.20 (100.8)	10.21 (100.9)	8.42 (83.2)	13.70 (135.4)
Sweet potatoes	6.11 (40.3)	16.99 (112.1)	8.86 (58.4)	4.83 (31.9)
Cocoyams	3.67 (73.4)	11.32 (226.4)	11.11 (222.2)	6.89 (137.8)
Irish potatoes	8.83 (57.4)	14.13 (91.9)	11.18 (72.7)	23.49 (152.7)
Carrots	12.74 (56.9)	19.71 (88.1)	19.11 (85.4)	29.07 (129.9)

Source: FAO (1985).
[a]Values in parentheses represent percentages of the world average.

Constraints to Increased Production and Utilization of Roots and Tubers

Low Yields

Except for yams, yields of roots and tubers in Africa are usually lower than the world's average (Table 13). In 1984, average yields of roots and tubers in Africa as a percentage of the world average ranged from 40.3% for sweet potato to 74.8% for cassava. The high African average yield in yams, which exceeded the world average, is partly because most of the world's yams are produced in Africa and some of the yams produced elsewhere for pharmaceutical purposes are not usually high yielders. The low yields are usually due to low soil fertility and rampant weed growth under short fallow periods, prevalence of diseases and pests, production in mixed culture, bias against roots and tubers, and research, development, and resource allocation.

Diseases and Pests

Diseases and pests greatly reduce yields of roots and tubers. Within the last decade, for example, cassava has been adversely affected by two new pests: the cassava mealybug (*Phenacoccus manihoti*) and the green spider mite (*Mononychellus* spp.), which are newcomers from Latin America. Yams suffer from nematodes, yam beetles, leaf spot, and viral diseases. Similarly, cocoyams are subject to attack by blight and the sweet potato yield declines under viruses, root-knot nematodes, and the sweet potato weevil (FAO 1986b).

Labour Shortage

Root and tuber crops have not been successfully mechanized and require considerable amounts of labour for land clearing and development, preplanting cultivation, planting, weeding, staking, harvesting, transportation, storage, and processing. The shortage of labour is often accentuated by the seasonality of operations and division of labour between the sexes. In Africa, labour on farms has to compete with more attractively paying jobs in other sectors of the economy.

Production Systems and Size of Holdings

Roots and tubers are largely produced by small farmers with limited resources and farms below 2 ha in over 70% of the cases. Smallholders lack credit to purchase inputs and their intercropping systems have been relatively neglected in research and extension, and are not compatible with some yield-raising inputs such as machinery, fertilizers, and chemicals. There are also socioeconomic problems such as land tenure and the absence of development strategies, which address problems of small farmers, especially women.

Inadequate Research and Extension Services

In addition to the relative neglect of root and tuber crops in research and extension until the last 10–20 years, shortages in research and extension personnel in sub-Saharan Africa were a major constraint. This is often exacerbated by rural infrastructure, emphasis on green revolution strategies, and related innovations that are inappropriate to roots and tubers and not adapted to the needs and circumstances of low-resource farmers.

Low Multiplication Ratio of Roots and Tubers

Roots and tubers are vegetatively propagated and multiplication of improved materials and their distribution pose special problems. Multiplication ratios of roots and tubers barely exceed 20 by most conventional techniques; cereals are generally over 70. Recent advances in tissue culture and rapid

multiplication promise to minimize these problems, but the techniques are still outside the capabilities of most national institutions.

POSTHARVEST TECHNOLOGIES

Roots and tubers, in addition to problems of harvesting, are too bulky to transport and handle. Because of their perishability, they also pose problems of storage. They have a low protein content and must be processed to enhance their fortification and use in composite flours. The increasing demand for convenience foods requires improved processing methods and equipment to ensure their availability in urban areas throughout the year. However, there are only limited food science capabilities in many African countries.

SOCIOECONOMIC CONSTRAINTS

Roots and tubers suffer bias in research, extension, resource allocation, and even consumption and utilization because they are regarded as "poor people's" crops and of a lower status than cereal staples. For this reason, there are often shifts among higher-income or urban classes toward cereals. In addition to such shifts, the availability of cereals in forms that are easier to store and handle enchances the demand for them and their products. Roots and tubers are only slightly involved in international and interregional trade and, therefore, there is a limit to moving them from surplus countries to areas of scarcity.

According to FAO (1986b), about 80% of roots and tubers in Africa are consumed by producing households and very small quantities are sold to distant markets, even within the same country. Most of those who sell these commodities in urban areas live close-by in the urban fringe. FAO (1986b) reports that the average percentage of roots and tubers marketed in Zaire is about 20%, in Sierra Leone and Zambia it is 3%. In Cote d'Ivoire, the average percentage marketed is 21%; however, there is a range from 8% in rural areas to 79 and 99% in other towns and Abidjan, respectively. Differences in percentage of roots and tubers marketed have been observed among crops and regions within countries in Madagascar, Nigeria, and Rwanda. Problems of marketing include those of collection and handling of bulky, small quantities of irregularly supplied produce of high water content and perishability passing through long marketing chains involving several intermediaries and varying periodic markets. The absence of an adequate marketing organization for roots and tubers makes farmers accept any price that is offered at the farm gate or local market by middlemen, who are able to process and transport goods to urban centres. Consequently, farmers receive only a small fraction of the final price. While data are lacking for detailed study of profitability of roots and tubers, FAO (1986b) reports higher gross returns for roots and tubers as compared with cereals because of their much higher yields at an often reduced cost of production. In many countries, there are policy constraints for producers of roots and tubers that result in more attractive prices and, often, the establishment of guaranteed minimum prices for cereals but not for roots and tubers (Jones 1972; FAO 1986b).

CONCLUSIONS AND RECOMMENDATIONS

The countries of sub-Saharan Africa produce roots and tubers in regions where there is greater stability in production from year to year and much less drought and damage by pests and diseases than in cereals. There is, therefore, a higher probability of achieving production targets and regional self-sufficiency in roots and tubers than in cereals. The role of roots and tubers as famine foods is well known, especially in drier areas. Despite their relative neglect in the past, there are developments that favour an increased production of roots and tubers. To enhance the realization of the full potential of roots and tubers, the following general recommendations are proposed.

GENERAL RECOMMENDATIONS

- African countries should formulate policies, adopt strategies, and plan, finance, and execute research and development projects specifically aimed at improving production and utilization of roots and tubers.
- Specific orientation conferences, workshops, and training programs should be used to minimize bias against roots and tubers and provide effective support for activities in the production, postharvest handling and processing, marketing, and utilization of root and tuber crops.
- Priority should be given to attaining food self-sufficiency through processing and utilization of roots and tubers as substitutes for cereals, which require more costly inputs, blending of root and tuber products with those of other crops to produce a range of foods that satisfy nutritional needs, and using scarce foreign exchange for importing cereal grains that cannot be profitably produced in Africa.
- Necessary measures should be taken to ensure an effective collaboration at disciplinary, institutional, ministerial, regional, and international levels in research and development activities on roots and tubers.

- Effective steps should be taken to institutionalize data collection and socioeconomic research on root and tuber crops production, processing, and utilization on a continuing basis to provide useful information for formulating policies and determining priorities and strategies in research and development of these crops.

SPECIFIC RECOMMENDATIONS

Adequate institutional infrastructure, trained support at all levels, and a range of research and development activities are essential to ensure the following:

- Improvement and development of high-yielding, early maturing, disease- and pest-resistant root and tuber varieties that require less production input and possess acceptable processing qualities;
- Development of integrated pest, disease, and weed management, and improved cropping systems for various ecological zones and production scales;
- Rapid propagation, multiplication, and distribution of improved planting materials;
- Development of appropriate technologies for production, processing, and food preparation; and
- More efficient and economical production of roots and tubers while maximizing returns to producers and finding solutions to the postharvest problems of roots and tubers.

Definite measures should be taken to ensure the linkage of research, training, and extension in root and tuber crops production, storage, processing, and utilization. Specific action programs should be launched to facilitate rapid and widespread adoption of improved production, storage, and processing technologies for these crops.

Postharvest problems of roots and tubers that should receive increased attention include the following:

- Handling, drying, transportation, and storage;
- Marketing and price incentives;
- Processing and packaging of products based on the study of traditional food preparations and utilization;
- Methods of using roots and tubers in composite flours that enhance their nutritional value;
- Consumer preferences in different regions and how to satisfy them with improved varieties and food processing; and
- Development of standardized methods of processing, certification, labeling, and quality control of root and tuber products.

Measures should be taken to develop farmers' organizations for production, marketing, and processing to minimize returns accruing more to middlemen than to producers.

International oganizations such as FAO, IDRC, and the African Regional Centre for Technology should be approached for technical assistance, research and training, funding of various activities, and dissemination and exchange of information and materials. The international agricultural research centres such as IITA and the International Centre for Tropical Agriculture (CIAT) also have special roles and advantage should be taken of their facilities.

Emerging biotechnologies, including tissue culture, genetic engineering, enzyme technology, and biomass technology, are potentially valuable in obtaining efficient production, processing, and utilization of roots and tubers. Linkage among special institutions in developing and developed countries can facilitate utilization of these technologies in a more cost-effective manner. However, with the exception of using the waste products of root and tuber processing, industrial utilization of roots and tubers should be given a lower priority until the demand for human consumption and animal feed has been satisfied.

The preceding recommendations are by no means exhaustive and more detailed recommendations are available (FAO 1986b). There are many recent developments in Africa that promise to enhance the priority being given to research, development, and improved utilization of roots and tubers in Africa. These include the following:

- The founding of ISTRC — AB;
- The decision by the federal government to ban wheat imports into Nigeria;
- Continuing interest by IDRC, FAO, etc., and, more recently, the United Nations Children's Fund (UNICEF), in supporting research and development activities in roots and tubers;
- The progress made in the biological control of the cassava mealybug, the green spider mite, and other pests and diseases of these crops;
- The development of improved micropropagation techniques and tissue culture facilities at IITA and elsewhere;
- The recent decision by OAU and the United Nations (UN) to support special programs to ensure food self-sufficiency in Africa along the lines of the Lagos Plan of Action;
- The fall in prices of cassava and cassava products and the convening of a special workshop by the Federal Department of Agriculture to find ways of encouraging more efficient utilization and increasing demand and higher prices for producers of these crops;
- The Committee of World Food Security recommendations on importance of roots and tubers

and ways for ensuring their increased production and utilization; and

- The support of this triennial symposium by individuals, government ministries, various organizations, and institutions.

We should take full advantage of these developments in finding funds for the training of research and development personnel and for the utilization of roots and tubers as effective weapons for fighting the African food crisis.

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CLOSING RECOMMENDATIONS

The final session of the symposium was devoted to discussions that provided the basis for a synthesis of symposium deliberations and resulted in the following eight recommendations.

First, efficient postharvest technologies should be developed to reduce losses and to ensure the availability of high-quality processed food, feed, and industrial products from root and tuber crops.

Second, a network of scientists and institutions should be developed under the auspices of ISTRC — AB for effective collaboration in root crops research in Africa.

Third, major consideration must be given to the development of drought-tolerant varieties of root and tuber crops adaptable to arid and semi-arid environments, and investigations must be made into the potential for irrigation of root crops in these areas.

Fourth, definite action must be taken through publications, workshops, and conferences to ensure that the current bias against root and tuber crops is minimized not only with respect to their consumption and utilization but also with respect to those policy issues and national priorities that affect the allocation of resources.

Fifth, current and future research should immediately focus on the reduction of production costs. The economics of production, storage, processing, utilization, and marketing (including export) should also be critically reviewed to ensure fair prices that will encourage and sustain increased production.

Sixth, ISTRC — AB should encourage national programs to collect and compile accurate statistics on the production and distribution of the major root and tuber crops and other crops in Africa for policy and planning purposes.

Seventh, root crops researchers must standardize their terminologies, methodologies, and systems of field scoring and evaluation as much as possible to ensure meaningful communication in areas of mutual interest.

Eighth, and finally, in view of the hazards attendant on the indiscriminate use of agrochemicals in tropical environments, immediate action must be taken to monitor more accurately the marketing, usage, and safety of the agrochemicals recommended for use in root and tuber crops production.

CASSAVA BREEDING AND AGRONOMY

CASSAVA AND THE AFRICAN FOOD CRISIS

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Cassava is the most important root crop grown in the tropics. Because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions, and suitability to present farming systems in Africa, cassava could play a major role in alleviating the African food crisis. Improvements in available varieties, cultural practices, and processing techniques would increase cassava production and utilization. The potential of, and constraints to, cassava production in Africa are discussed.

Cassava accounts for approximately a third of the total staples produced in sub-Saharan Africa (FAO 1986). Cassava is grown almost exclusively as food in 39 African countries, stretching in a wide belt from Madagascar in the southeast to Senegal in the northwest (Hahn and Keyser 1985), where the annual rainfall exceeds 900 mm, falling over a period of 120–150 days, and the altitude ranges from sea level to 2000 m. Four African countries (Mozambique, Nigeria, Tanzania, and Zaire) are among the 10 largest cassava producers in the world.

Cassava has a comparatively high biological efficiency of food-energy production because of rapid and prolonged crop growth and produces 2.2 times more calories per hectare than maize (FAO 1986), with a lower resource cost (Hahn et al. 1979; Ikpi et al. 1986). Cassava's virtue as a human food item is that it is a cheap and abundant source of energy (Ikpi et al. 1986). The 10 countries in the world whose food energy comes mostly from cassava are in Africa: Angola, Benin, the Central African Republic, the Comoros, the Congo, Liberia, Mozambique, Tanzania, Togo, and Zaire (Horton et al. 1984). The stability of cassava production, measured using the yearly coefficient of yield variation from 1966 to 1986 (cassava, 4.3%; maize, 36.2%), is the highest among the major world food crops (TAC 1985). The cassava crop is a storage root; it can be kept underground from 6 to 36 months after planting and is thus always available to farmers. A hardy plant, cassava has the ability to recover from severe climatic stress (particularly drought) or pest and disease attacks when favourable conditions return; yields are reasonable under marginal soil conditions.

Cassava tubers are prepared in many ways, depending upon local customs and preferences, and form the basic carbohydrate element of the diet. The leaves, consumed as a preferred green vegetable in many parts of Africa, provide protein, minerals, and vitamins. Processing is required to remove cyanide and improve palatability before tubers and leaves are consumed (Hahn 1984).

This paper reviews the potential of, and the constraints to, cassava production in the African farming and food systems and relates these to the current African food crisis and to the future food-production needs of the continent.

CASSAVA IN THE FARMING AND FOOD SYSTEMS

Cassava was first introduced into Central Africa during the last part of the 16th century, into West Africa in the early 18th century, and into East Africa in the early 19th century (Jones 1959). Cassava is thus a relatively new crop to African agriculture. The crop was rapidly adopted by farmers and integrated into the traditional farming and food systems of Africa because of the following factors:

- adaptability to traditional farming and food systems,
- relative ease of cultivation and processing,
- year-round availability and insurance against crop failure,
- low input or resource requirements, and
- relatively high yield of food energy (calories) per calorie of labour input (Hahn et al. 1979).

Cassava's ability to adapt to short fallow periods facilitated its widespread cultivation, improved crop rotations, and combinations producing more food for more people (Morgan 1959). As a result, areas where

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cassava was introduced early are now the most densely populated parts of Africa (Morgan 1959), i.e. southern Nigeria, eastern and northern Tanzania, and western Zaire. The role of cassava in Africa is thus associated with population pressure, food security, and reduced fallow duration in bush fallow. This results in low soil fertility and a consequent demand for cheaper staple foods in urban areas (Okigbo and Greenland 1976).

Cassava is mainly regarded as a subsistence crop of low-income families or as a "famine-reserve crop," although it is more important than this. About 60% of the cassava output of households in the Oyo area of Nigeria (where yams and cereals have been dominant staples) is sold for processing (mostly into gari); the remaining 40% is consumed at home. People of all ages (2–82 years) and income levels in the area consume cassava in some form (Ikpi et al. 1986). This suggests that, in regions such as Oyo, the importance of cassava influences and is influenced by social needs, which are a result of population pressure, farm labour shortages and environmental degradation.

Decline in the Productivity of Farmland

Cassava is predominantly grown on Ultisols and Oxisols in the lowland, humid areas of tropical Africa (i.e., precipitation ≥ potential evapotranspiration for a 6–8 month period each year). These soils have low inherent fertilities and are difficult to manage. In these areas of Africa, increasing population pressures have drastically reduced fallow duration, resulting in poorer soils, low productivity (Hartmans 1981), and greater vulnerability of crops to drought.

The problem is a combination of soil conditions and climate. Most cassava-growing areas receive little rain followed by long periods of heavy rain in a year, such that cassava that is grown for more than 1 year experiences these two distinct seasons. Generally, soils of the humid tropics are structurally unstable and vulnerable to erosion because the ground flora is less developed; the humus layer is thinner and the organic matter undergoes more rapid biodecomposition under prevailing high temperature; and rains are more frequent and intense (Lal 1983).

The basin with farming based on an incomplete clearing (traditional system) lost a total of 9.6 mm of runoff and 0.03 t/ha of soil over 3 years at Ibadan, Nigeria, while mechanically cleared plots lost 580.6 mm of runoff and 15 t/ha of soil (Lal 1983). In Africa, the annual rate of new soil formation for Ultisols is estimated to be 0.011–0.045 mm, which means that it takes about 250–1000 years to develop 1 cm of fertile surface soil (Lal 1983). The soil exposed by erosion is not a favourable medium for root growth and tuber development and crops do not respond to fertilizers. This indicates the difficulty of regenerating useful surface soil and utilizing it for cassava production within a human lifetime once the surface soils are lost through erosion. The authors have often observed in tropical Africa that even weeds do not come back to farmland where severe erosion has occurred.

Soil splashing is negatively correlated with the leaf area index ($r = -0.93$) and soil erosion decreases exponentially with increased canopy cover (Lal 1983). Cassava has an open canopy during its first 3–4 months and, therefore, the soil under it is more susceptible to erosion than the soil under maize, whose canopy develops quickly; however, cassava varieties or crop combinations that establish an early canopy and close canopy cover protect the soil against the impact of rainfall.

Cassava does not tolerate excess soil water and is thus grown on well-drained uplands or on large mounds or ridges in waterlogged soils. Although cassava can survive 4–6 months of dry weather, soil moisture stress retards growth (Ike 1982), more so with poor root systems in soils of high bulk density (Lal 1981).

Unwarranted Blame on Cassava

Cassava is normally grown last in cropping sequences before bush fallow because it does not respond as well as cereals to good soil and cereals do not perform as well as cassava on poor, overcropped soils. Consequently, the soil is significantly less fertile when the cassava is planted. Yet, cassava, being the last crop, gets the unwarranted blame for soil degradation. Continuous or frequent cultivation of cassava does, in fact, degrade the soil; however, this is more evident with annual food crop species.

Cassava is considered inferior by many eaters and noneaters of cassava simply because it is low in protein, although cassava leaves (as a vegetable) contain 26.1% quality protein on a dry-weight basis (Hahn 1983). When people die from paraparesis after consuming a diet containing cassava, cassava is exclusively blamed because of its cyanide content, although the diet may also have contained other cyanogenic plants, toxic mushrooms, or other toxic substances. In the Memba district of northern Mozambique, there was a severe drought in 1981 and all crops completely failed except cassava. Being a staple there, many people ate inadequately processed cassava lacking protein-rich supplements. Over 1000 people showed symptoms of spastic paraparesis after consumption (Rosling 1986). Under such unusual

famine conditions, cassava, which was the sole survivor of the drought, was available to feed people and, therefore, got all the blame for the ensuing paraparesis. Without cassava, however, many thousands of people would have starved to death, including those who showed symptoms of paraparesis. Kerala State is the only state in India that, in spite of its high population, has never experienced famine. This is due to extensive cassava cultivation.

When there is a high incidence of endemic goitre, it is primarily blamed on cassava. Cassava, however, is not the only goitrogenic plant. Certain organic compounds and bacterial contamination in drinking water are also goitrogenic. An iodine deficiency in drinking water or excess iodine intake can also cause goitre (Gaitan 1983).

Cassava is commonly blamed for malnutrition because the roots contain little protein, and this is further reduced during processing. These nutritive deficiencies need not cause malnutrition, however, because the poorest families (in rural and urban areas) do not consume cassava products alone. It is always eaten with other dishes that provide those nutrients not present in cassava (Ikpi et al. 1986).

The absence of cassava in the present farming and food systems of Africa would lead to catastrophic levels of starvation and death for millions of people. Cassava deserves a special position as a crop that has saved many lives in Africa.

Farm Resources: Fertilizers

Fertilizers are essential in modern farming. Farmers in Africa annually apply about 18 kg/ha to their cropland compared with 67 kg/ha in Asia and 218 kg/ha in western Europe. The amount of fertilizer nutrients used annually in the whole of Africa is about the same as that used in West Germany (Sheldon et al. 1984).

Cassava responds to fertilizers under marginal soils; however, fertilizers are useful to cassava only if chemical, physical, and biological properties of soils are adequate. Therefore, many of the cassava soil problems cannot be resolved by simply applying chemical fertilizers. Furthermore, fertilizers are not easily available to farmers at reasonable prices and it is not likely that the situation will improve in the near future in many parts of Africa.

Performance of Cassava Under Environmental Stress

Cassava is known for its ability to produce appreciable carbohydrate yields on soils too poor to sustain the growth of other crops (Asher et al. 1980). African soils under cassava are overcultivated and have low fertility, high acidity and aluminium levels, low organic matter, are shallow and highly compacted, retain little soil moisture, and are high in soil temperature at certain times of the year. Cassava yields 2.0 t/ha on soils in eastern Nigeria, where population density is high (750–1000 persons/km^2), that are low in N (0.09 mequiv./100 g), P (9.77 mequiv./100 g), K (0.11 mequiv./100 g), and organic compounds (1.20%), are highly acid (pH 4.45) (Lagemann 1977), low in cation exchange capacity (2.5 mequiv./100 g), and have a base saturation of only 19% (Edwards and Kang 1978). In this soil, cassava gave 79 or 80% of the maximum yields obtained at moderate rates of lime application (1.0–1.6 t/ha), while sorghum and cowpea gave only 9.5 and 52%, respectively. Maize seedlings perished shortly after emergence (Edwards and Kang 1978). This indicates that cassava peforms better than any other food crops on soil of low fertility and high acidity and that cassava is highly acid tolerant, exhibiting little or no yield reduction at soil pH values as low as 4.3 (Edwards and Kang 1978). Cassava also tolerates high aluminium concentrations (Edwards and Kang 1978) and low pH better than any other crop and it can tolerate up to 90% aluminium saturation of the cation exchange complex of the soil. Cassava is also tolerant of calcium deficiency (Edwards and Kang 1978).

When the soil is dry, cassava has the ability to obtain water from a greater soil depth (Ghuman and Lal 1983). The physiological ability to retain water in arid conditions is high. The water and nutrients re served in the cassava tubers and stems during the rainy periods seem to be well mobilized to retain leaves and continue physiological functions when the plants are undergoing short dry periods.

During drought stress, cassava follows a conservative pattern of water use by reducing leaf area index and closing its stomata, hence, reducing potential transpiration. Leaves that remain on the plants have a remarkable ability to photosynthesize actively when moisture becomes available (Cock 1982). The plant slows its growth during drought periods but rapidly recovers when moisture levels improve, hence, its ability to tolerate drought stress.

The range of optimum root zone temperature is slightly wider for cassava than for grain crops such as maize or soybean (Lal 1981), although a soil temperature exceeding 35°C in the root zone coupled with a low soil moisture availability can result in a significant yield reduction (Okigbo 1979).

Cassava forms effective mycorrhizal associations in the roots, which increase its efficiency of phosphorous uptake and utilization. Inoculation of cassava with a mycorrhizal fungus, *Glomus mossea*, led to a significant increase in dry matter yield and

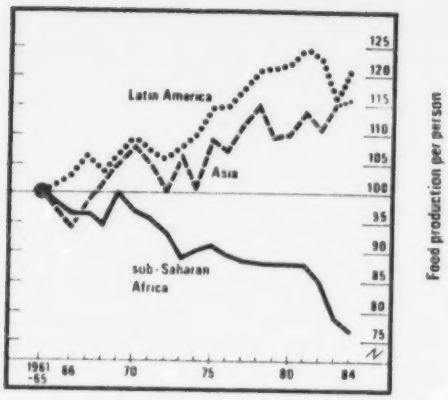

Fig. 1. *Food production per person (1961–65 average = 100) in sub-Saharan Africa in comparison with Latin America and Asia. Source: adapted from* The Economist, *May 1985.*

phosphorous uptake of cassava (Hahn et al. 1981).

Soil erosion–yield and runoff–yield ratios were higher with cassava than without cassava in the cropping sequence (Lal 1983), indicating that more yield with less soil erosion and runoff can be achieved with cassava. This is because soil erosion decreased exponentially with increases in cassava canopy cover (Lal 1983). Cassava varieties or crop combinations that establish an early, close canopy cover protect the soil against the impact of rainfall. Traditional mixed cropping of cassava with maize or groundnuts and other crops resulted in less runoff and soil loss than did monocropped maize or cassava (Lal 1983).

At full canopy, cassava completely shades the weeds, reducing labour requirements for weeding. Cassava suffers less damage by animals such as birds, rodents, and monkeys than do other food crops.

Cassava in Relation to the Food Crisis

Food production per capita in Africa is decreasing; in Asia and Latin America, it is increasing (Fig. 1). The food crisis in Africa is neither a sudden natural disaster nor simply caused by a lack of rainfall. It is the result of a combination of interrelated factors: too little rain, poor soil, plant diseases and pests, and socioeconomic factors (Timberlake 1985). The food crisis results from a breakdown in the relationship between people and environmental support systems (Timberlake 1985).

The annual cassava production in Africa since 1950 has shown a steady increase, but has not kept pace with population growth since 1980 (Fig. 2). In general, increased output occurred because of an increased cultivated area rather than increased yields (FAO 1986). The poorer the land, the larger the area of land needed for cassava production. Low cassava yields caused by diseases and pests necessitate a compensatory expansion of the area devoted to cassava cultivation. The projections of demand for roots and tubers including cassava in the year 1995 based on their past (1966–81) production trends indicate that production would increase by only 22×10^6 t, while the total demand for roots and tubers in Africa would increase by 42×10^6 t, implying a deficit of 20×10^6 t (FAO 1986). Unless the output of roots and tubers (primarily cassava) increases, the deficit will most probably have to be met by cereal imports, which are expensive. At current prices, the cost of such cereal imports could reach USD 1 billion year (FAO 1986).

Food aid given or sold at concessionary rates to African governments tends to depress local farm prices and drastically reduces consumption of local foods, particularly cassava, in the cities. The consumption of bread made of imported wheat is a trend that has spread from the larger cities to many towns and villages. The result is a shift in consumption patterns toward imported cereals. Cheap food imports benefit the cities and weaken the rural areas. Urban development is attracting people into the cities, resulting in a shortage of farm labour (Timberlake 1985).

Planting the best land with cash crops such as sugarcane and tea — which almost invariably use less labour than food crops — pushes large numbers of subsistence farmers into more marginal, unsuitable land. Food crops suffer, not only from land and

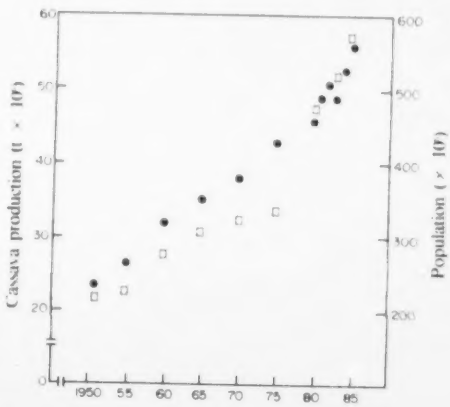

Fig. 2. *Cassava production (●) and population growth (□) in Africa.*

labour shortages, but also from general neglect by research and extension workers and marketing boards; the suffering of the cassava crop is most evident. Cash crops get more help, advice, and credit than cassava not only from governments but also from national and international developing agencies and development banks; they also get more research funds toward improving yields and developing varieties resistant to drought, diseases, insect pests, etc. (Timberlake 1985).

Many African countries desire the cereal-based green revolution experienced in Asia and Latin America, but government policies have not supported such desires in many parts of sub-Saharan Africa where agroecological conditions are not suitable for cereal crops and lack similar infrastructures (FAO 1986).

Future Perspectives

The tolerance of cassava to extreme stress conditions, its biological efficiency in the production of food energy, its low production resource requirements, its availability throughout the year, and its suitability for farming systems will make cassava more popular to farmers in Africa. With improved varieties, cultural practices, and processing, cassava yield and product quality (i.e., gari, one of the best processed food products in terms of convenience in utilization, preservation, and transportation in Africa) could be equaled or bettered with less land and labour. For these reasons, cassava has a great potentail as a crop of the future in Africa's struggle to attain household food sufficiency and security through increased production and utilization (Ikpi et al. 1986). The African food crisis encompasses not only the shortage of human food but also the critical shortage of livestock food. Drought, for instance, affects food that should feed both humans and livestock. The hardy cassava plant could, therefore, play a significant role in the future as a feed for livestock in Africa. The future of cassava in African countries depends on the policies and activities of governments and agencies of the United Nations that affect its cultivation (Ikpi 1986). Irrespective of government policies, however, cassava will undoubtedly remain an important staple of millions of people in the foreseeable future in Africa.

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EVALUATION OF NITROGEN FERTILIZER SOURCES AND RATES FOR A CASSAVA–MAIZE INTERCROP

B.O. NJOKU AND S.O. ODURUKWE[1]

Three readily soluble nitrogen (N) fertilizers — sulphate of ammonia (SA), calcium ammonium nitrate (CAN), and urea — and two slow-release forms — sulphur-coated urea of 11% (SCU-11) and 30% (SCU-30) dissolution rate in 7 days — were each tested at four rates on a cassava–maize intercrop for two cropping seasons in the high rainfall zone of Nigeria. Cassava plots that were treated with CAN produced significantly higher tuber and starch yields than those that received SA and the two slow-release forms. Urea was the second-best N source, although plots treated with urea did not yield significantly higher than other plots. Maize dressed with urea produced significantly higher grain yields than those that received N from other sources. Increasing the rate of N applied up to 100 kg N/ha produced a higher significant increase in maize grain yield and a nonsignificant depression in cassava tuber yield. Total energy yields from CAN-treated plots were significantly the highest. The results indicate that 100 kg N/ha in the form of CAN or urea is best for cassava–maize cultivation in this high-rainfall zone.

Cassava (*Manihot esculenta* Cranz) is a major staple food in Nigeria. In the southern part of the country, it is often intercropped with shorter duration crops such as maize, cowpea, egusi, and leaf vegetables. Cassava–maize is the dominant crop combination in the farming systems of this region because the maize matures and provides food when many other food items are scarce.

Although intercropping has several advantages (Okigbo and Greenland 1976; Ezumah and Okigbo 1980), there is the difficulty of applying fertilizers and herbicides for the benefit of the component crops in mix-cropped systems, as well as the difficulty of mechanization. Disparity in the period of high nutrient demand by the crops could lead to low efficiency of utilization of applied fertilizer, especially for crops with unequal field duration. Fertilizer applied to a Kaolinitic ultisol is quickly leached from the surface horizons (Pleysier and Juo 1981; Arora and Juo 1982) and a high proportion of nitrogen (N) applied to the cassava–maize intercrop was lost in the drainage water (Njoku et al. 1984).

There is a dearth of information on fertilizer practices for multiple cropping. Nitrogen management in maize-based intercrops such as maize–rice (IRRI 1974), maize – pigeon pea (Dalal 1974), and cassava – maize (Oelsligle 1974) has been reported.

Tentative fertilization in multiple cropping, depending on broadcasting and incorporation of relatively immobile nutrients at the time most suitable for the cropping pattern, has been suggested (Oelsligle et al. 1976). Mobile nutrients can be topdressed at a compromise time for the requirement of the component crops. Kang and Wilson (1981) observed that maize intercropped with cassava showed a significant response to N; however, the cassava crop showed no significant response.

This paper reports on the efficiency of five N fertilizer sources in a cassava–maize intercrop.

MATERIALS AND METHODS

The trial was conducted in 1981 and 1982 at the Research Farm of the National Root Crops Research Institute at Umudike (05°29′ N, 07°33′ E), where the mean annual rainfall is 2170 mm. The soil is a sandy loam, Kaolinitic typic paleudult. Some chemical properties of the surface soil prior to cropping are as follows: pH (in 1:1 soil–water mixture), 5.4; organic C, 1.32%; total N, 0.12%; extractable Bray – 1 P, 5.6 ppm; 1 *N* NH_4 – acetate extractable Ca, Mg, K, and Na, 1.92, 0.27, 0.13, and 0.04 mequiv./100 g, respectively; exhange acidity, 0.82 mequiv./100 g.

Three readily soluble N fertilizers — sulphate of ammonia (SA), calcium ammonium nitrate (CAN), and urea — and two slow-release forms — sulphur-coated urea of 11% (SCU-11) and 30% (SCU-30)

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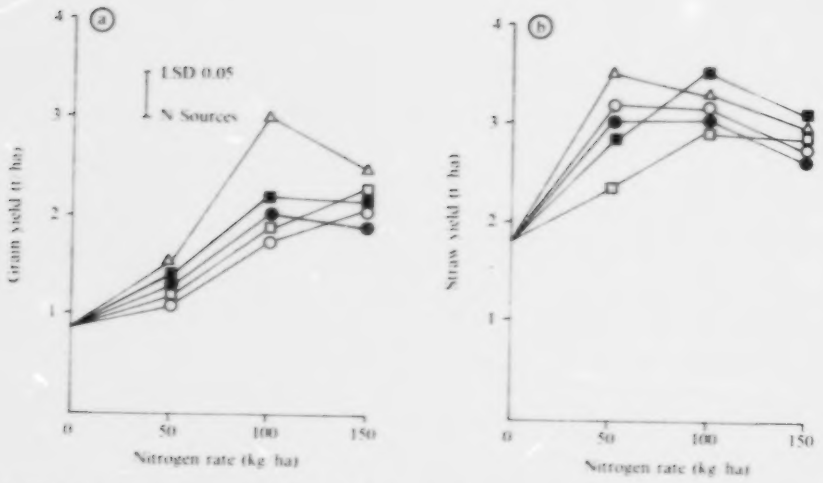

Fig. 1. *Effect of nitrogen sources and rates of application on maize grain (a) and straw (b) yields. Sources:* ●, *SA;* ○, *CAN;* △, *urea;* □, *SCU-11;* ■, *SCU-30.*

dissolution rate in 7 days — were each tested at four rates: 0, 50, 100, and 150 kg N/ha. Cassava variety TMS 30211, ideal for intercropping with maize (Ezeilo 1978), and maize variety FARZ 27 were planted on 19 May in flat, alternate rows at populations of 10 000 and 40 000, respectively. A basal dressing of 120 kg K/ha as muriate of potash, 40 kg P/ha as single super phosphate, and 10 kg Mg/ha as magnesium sulphate was applied to each plot. All fertilizer treatments were broadcast 2 weeks after planting. The experiment was laid in a split-plot design in randomized complete blocks with three replicates. Nitrogen rates were assigned to the main plots; N sources, to the subplots. In 1982, the experiment was repeated on an acid soil (pH 4.7). Lime was applied at a rate of 2 t/ha 1 week before planting on 14 April. The cassava suffered from severe drought for about 4 months.

At maturity, maize straw weight and grain yield were recorded. Cassava was harvested at 12 months for tops and fresh tubers. Representative samples of at least three tubers from each plot were selected and analyzed for starch and dry matter immediately after harvest. When this could not be completed, samples from the same replicate were kept in sealed polythene bags and stored in the refrigerator and the analysis was completed the following day. Starch was extracted from the pulp and determined after Obigbesan (1977). Energy yields were computed using the values in Oyenuga (1968). Statistical analysis was carried out using the combined data for both years.

Results

Maize Yield

Maize treated with urea had a significantly higher grain yield than maize treated with SA, CAN, or SCU-11 (Fig. 1a). Urea treatment resulted in a nonsignificant higher grain yield than the SCU-30 treatment.

Each increment of N up to 100 kg/ha produced an increased grain yield ($P = 0.01$), but grain yield decreased by 4% at higher rates. Maize straw yield was not significantly affected by the N sources (Fig. 1b), although it was higher with urea than with the other N sources by 4–16%. The application of 50 kg N/ha significantly ($P = 0.01$) increased straw yield over the control. Higher N rates only slightly increased yield up to 100 kg/ha. The interaction between N rate and N source was not significant for maize grain or maize straw but was significant between year and source for maize straw.

Cassava Yield

Plots treated with CAN produced higher fresh yields of cassava tubers than those fertilized with other N sources, but the differences were not significant (Fig. 2a). The yield increase ranged from 11% in urea-treated plots to 21% in plots treated with SCU-30. Tuber yield from the control plot was surpassed only by the yield from CAN-treated plots and

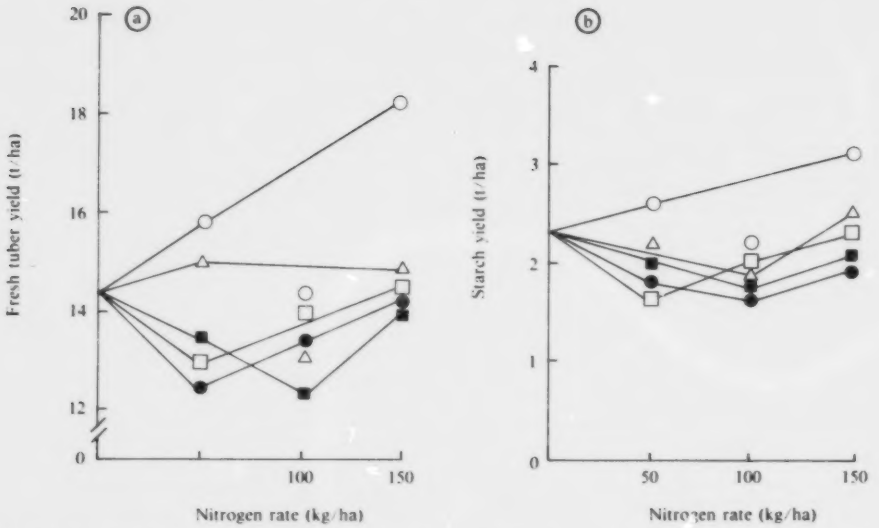

Fig. 2. *Effect of nitrogen sources and rates of application on cassava fresh tuber (a) and starch (b) yields. Sources:* ●, *SA;* ○, *CAN;* △, *urea;* □, *SCU-11;* ■, *SCU-30.*

was depressed by 3.3 and 7.2% in plots with 50 and 100 kg N/ha, respectively.

Starch yields from CAN-treated plots were significantly higher (16–35%) than plots treated with SA, SCU-11, or SCU-30 (Fig. 2b). With the exception of CAN plots, starch yields from other plots were 3–16% less than the control. Starch yield was depressed by 11% when up to 100 kg N/ha was applied. The yield of tuber dry matter (not shown) followed the same trend as the yield of starch.

Interaction between N rate and N source was not significant for any of the yield parameters of cassava. The utilization index (UI), a measure of the ratio of tuber weight to the weight of tops, was low: 0.69, 0.66, 0.62, 0.58, 0.58, and 0.69 for plots treated with SA, CAN, urea, SCU-11, and SCU-30, and the control plot, respectively. Plots treated with CAN yielded significantly higher energy than those treated with other N sources (Table 1). Again, urea was the second-best N source. There was a linear, but nonsignificant increase in energy yield with higher N applications (Table 1). Energy yield from maize was about 20% of the yield from cassava (not shown).

Table 1. The influence of different N sources and N application rates on the total energy yield ($\times 10^6$ cal/ha) in cassava–maize intercrop.

N source	Energy yield	N rate (kg/ha)	Energy yield
Control	30.65	0	30.65
SA	32.97	50	32.71
CAN	40.00	100	35.51
Urea	38.61	150	38.00
SCU-11	33.09		
SCU-30	32.38	SE[a]	2.61
LSD ($P = 0.05$)	5.92		

[a]Standard error.

DISCUSSION

The magnitude and intensity of rainfall in southeastern Nigeria result in high leaching of applied nitrogen. The use of slow-release forms of N fertilizer to improve the N available to cassava in a mixture with maize resulted in lower yields than those obtained when readily soluble forms were used. This could be due to either the cassava not responding to N or the N release being too slow.

Calcium ammonium nitrate (followed by urea) was the best N fertilizer source for the cassava–maize mixture. Both produced higher crop yields, even though applied only 2 weeks after planting. The efficiency of CAN may be attributed to its supply of calcium to this calcium-deficient soil, an effect that was more marked in 1981 than in 1982 when lime was applied. This result agrees with a previous report (Abruna-Rodriguez et al. 1982).

Nitrogen application rates up to 100 kg/ha increased the yield of maize but lowered cassava yields. The yield depression was partly due to competition for water and nutrients with maize and the tendency of N to induce more shoot than root growth. This is reflected in the low UI values obtained (0.58–0.69). This compares unfavourably with reported UI values of 0.60–0.84 (Obigbesan 1973) with a sweet cassava variety (*Manihot palmata* Pohl), and UI values of 1.31 and 1.34 for bitter cultivars 53101 and 60506, respectively. The cassava variety used in this study, however, is known to be low yielding, and a lack of response of cassava to applied nitrogen has previously been reported (Kang and Wilson 1981). The results of this investigation indicate that either CAN or urea at the rate of 100 kg N/ha is suitable for a cassava–maize intercrop, especially because both of these fertilizers have a low residual acidity.

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ABSTRACTS

INCREASING THE PRODUCTIVITY OF CASSAVA–MAIZE INTERCROPS WITH GROUNDNUTS (*APIOS HYPOGEA*)

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Studies were initiated in 1983 to investigate the effects of intercropping cassava, maize, and groundnuts in a low-fertility soil on the yield of the component species, the gross economic returns, and the total productivity of the land. Where the groundnut population did not exceed 100 000 plants/ha, cassava–maize and cassava–groundnut intercrops yielded as much cassava root as did cassava alone. Cassava root yield decreased by 20% in a cassava–maize–groundnuts intercrop where the groundnuts population was ≥100 000 plants/ha. The low maize yields in mixed cropping systems were attributed to the 50% of sole crop population used. The yield of maize grain per plant did not differ between cropping systems. Groundnut populations of 50 000 and 200 000 plants/ha caused significantly low pod yields of 67 and 78%, respectively, when intercropped with cassava–maize. The corresponding reduction in groundnut yield at 100 000 plants/ha was only 10%. This study indicated that a cassava–maize–groundnut intercrop is more productive than cassava–maize or cassava–groundnut intercrops, provided the groundnut population is less than 100 000 plants/ha.

EFFECT OF CASSAVA INTRODUCTION TIME INTO MAIZE ON INTERCROP YIELDS

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The time of planting for cassava is flexible; however, maize must be planted within a narrow time span to maximize biological yield. In a cassava–maize intercrop, cassava establishment through maize may be limited by shading and an early cessation of rain. To determine the flexibility of cassava planting time, cassava was introduced through maize in two environments in Nigeria and Zaire. More efficient land use was attained with cassava–maize intercropping irregardless of the time of cassava introduction. Early introduction (planting on the same day to 5–8 weeks delay) resulted in no cassava yield reduction. The limits to cassava introduction time appear to be related to the duration of rainfall. Maize yield was not affected by the cassava variety or the date of cassava introduction.

EFFECT OF TIME OF CUTTING BACK CASSAVA STEMS ON THE YIELD AND QUALITY OF ROOTS

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In traditional farming systems, cassava harvesting involves first cutting back the stems and then, some days later, harvesting roots. This study investigated the effect that the time of cutting back the cassava stems had

upon cassava performance. Cassava clone TMX 30211 was planted in the field and cut back once during the study period at 3, 6, 9, and 12 months after planting (MAP). The control was left uncut. Cutting back cassava stems significantly reduced root yield by 14.3%. Yields from plots cut back at 9 MAP (37.7 t/ha) and 12 MAP (38.1 t/ha) were not significantly different from the control (40.9 t/ha) but were significantly higher than those plots cut back at 3 MAP (31.3 t/ha) and 6 MAP (33.1 t/ha). Plant height and mean number of roots per plant were similarly affected by the treatments. Root mean weight, leaf area index, and root quality, however, were not significantly affected.

PERFORMANCE OF IMPROVED CASSAVA CLONES IN THE SANDY, LATERITIC SOILS OF THE SOUTHERN LOWLANDS OF CAMEROON

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Cassava yield trials conducted in three environments in the Central Province of Cameroon showed that superior clones performed best, yielding over 20 t/ha at each location. These clones outyielded local cultivars. Higher yields appeared to be associated with tolerance to cassava mosaic disease. At Ntui, Cameroon, a severe outbreak of cassava bacterial blight in 1985 drastically reduced the yields of most clones, possibly because these clones were developed at Nkolbisson, Cameroon, an area free of cassava bacterial blight. This study suggests the need to test improved clones for their tolerance to major diseases and pests before their release. Of the eight clones tested in farmers' fields, clone 1005 had the highest yield of roots and leaves and was preferred by all growers participating in the trial.

EFFECT OF PLANT DENSITY ON THE YIELD AND YIELD COMPONENTS OF CASSAVA IN MALAWI

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Cassava variety × plant density trials were conducted for three seasons at Mkondezi, and for one season at Vinthukutu, in northern Malawi. At Vinthukutu in the 1982/83 season, increased cassava densities neither increased yields nor reduced final plant populations at harvest. As density increased from 21 000 to 63 000 plants/ha, however, there was a significant reduction in the total number of roots harvested per plot for both cassava varieties. At Mkondezi, results for the 1982/83 and 1983/84 seasons showed that higher densities did not increase yields. In the 1984/85 season, however, higher densities significantly reduced yield. Also at Mkondezi, there were significant differences in the number of roots harvested per plot between the 1982/83 and 1983/84 seasons and between varieties in the 1984/85 season. Increased plant densities significantly reduced the number of roots harvested per plot in the 1983/84 and 1984/85 seasons but not in the 1982/83 season. The importance of these results with respect to the availability and quality of planting materials in Malawi is discussed.

IMPROVEMENT OF CASSAVA (*MANIHOT ESCULENTA*) BY IN VITRO CULTURE

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Since cassava was introduced to Africa, it has adapted and become broadly diversified. The Congolese program for the selection of bacteria-resistent cassava has recorded a wide range of genetically rich material, indicating that national research programs should conserve or improve the well-adapted local vegetable resources. In this study, in vitro culture experiments were performed on cassava. Results showed that cassava could easily be manipulated in vitro. This study demonstrated that entire cassava plants could be produced from young tissues such as cauline meristems and cotyledons. Cellular fusions were also achieved with cells and protoplasts (cassava cells are highly allofusive). A somatic emryogenesis can now be obtained from protoplasts. This study shows that in vitro culture techniques can be used to improve local cassava varieties.

YAM BREEDING AND AGRONOMY

YAM AND THE AFRICAN FOOD CRISIS

O.O. OKOLI[1] AND I.C. ONWUEME[2]

Chronic food shortages have persisted in parts of sub-Saharan Africa for more than 10 years. The situation is deteriorating because of declining rates of per capita food production in most of these countries. Natural disasters (e.g., drought, flooding, and desertification), civil disturbances, and wars have resulted in population drift and have aggravated what is now commonly referred to as the African food crisis. This crisis, in essence, is one of insufficient food energy. For mostly ethnocentric reasons, yam, an energy-rich food produced and eaten widely in the wetter parts of sub-Saharan Africa, has failed to play a significant role in alleviating hunger and famine in drought-affected areas and in refugee camps of Africa. An increased role for yams in supplying needed carbohydrates to most of Africa is highlighted. The need for more intensive research to reduce cost and operations in yam production, processing, utilization, and storage is also stressed. Results from such research will enable yams to complement cereals in drought-affected areas of Africa and to contribute more to the human diet in areas where yams are produced.

Recent estimates allocate 20% of the 730×10^6 undernourished people of the Third World to sub-Saharan Africa (World Bank 1984). Although the increase in global food production exceeded population growth, and cereals prices in world markets declined from 1970 to 1980, because of high population growth, the proportion of people with inadequate caloric diets has increased in this same period. "Lack of purchasing power" is the major reason the poor of the Third World cannot share in the global food abundance.

Famine, or chronic food insecurity, is the continuous dependence on an inadequate diet because of an inability to acquire food. Famine persists worldwide and has shaped the 19th century history of Europe and America (e.g., the famine caused by potato blight in the British Isles and most of continental Europe). Famine results in a locality when the supply of food that is affordable to the majority is inadequate. An inadequate food supply, in turn, results from meager cultivation or poor harvests. Meager cultivation occurs when populations are unstable as a result of wars or natural disasters (e.g., desertification, drought, floods, etc.), while poor harvests may be due to factors such as poor weather (causing drought, flood, etc.) or the attack of pests and diseases.

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DIMENSIONS OF THE AFRICAN FOOD CRISIS

The present African food crisis has resulted from natural and man-made phenomena combined with tenuous food policies. The 9-year war in Ogaden together with severe drought has caused famine of unprecedented magnitude in Ethiopia. Wars and civil disturbances in Chad, the Sudan, and Uganda from 1975 to 1985 have resulted in mass movements of refugees. Desertification in the Sahel zone of West Africa because of drought, poor land management, and overgrazing is also causing significant famine and migration from dry to humid areas. Traditional crop and livestock outputs were significantly reduced by both the mealybug and green spider mite of cassava, which followed the dry spell of the late 1970s, and by the rinderpest epidemic, which decimated millions of cattle in the West African savannah between 1981 and 1984.

Furthermore, the food policies of most African countries are both poorly articulated and poorly executed. The policies are unable to accomodate the high population growth rates of these countries. Nigeria's Fourth National Development Plan projected a 4% growth rate for crops and livestock, although planners were aware that respective rates of 6.6 and 11.3% were needed for self-sufficiency by 1985. Nonetheless, only slightly over 1% growth was achieved over the 5-year period (Central Bank of Nigeria 1983). Abdullahi (1985) blamed this poor performance partly on inconsistent, contradictory

Table 1. Import of consumer goods (NGN × 10^6) from 1972 to 1978 in Nigeria.

Goods	1972	1973	1974	1975	1976	1977	1978
Food	99.4	131.4	166.4	353.7	526.7	912.6	1004.2
	(23.5)[a]	(35.6)	(37.8)	(36.1)	(39.0)	(46.2)	(47.0)
Textile	153.4	36.6	31.5	81.5	65.0	38.9	41.9
Other nondurable goods	118.5	138.7	173.6	353.5	476.7	612.1	720.5
Durable goods	51.3	62.9	68.5	191.3	282.0	412.7	370.2
Total	422.6	369.6	440.0	980.0	1350.4	1976.3	2136.8

Source: Nigeria, Federal Office of Statistics (1978).
[a]Values in parentheses represent food imports as a percentage of the total import of consumer goods.

policies of governments, with resultant adverse effects on the economy, especially in the agricultural sectors. Neglect of agriculture in general and, in particular, food crop production by the Nigerian government since the early 1970s also contributed to the poor growth rate. In the 1960s, agriculture contributed up to 60% of the country's total foreign exchange earnings; however, in 1985, Nkwocha noted that "agriculture became reduced to a near stagnant growth of one quarter of the yearly population growth and 18% of the G.D.P." Efforts to counter this trend (Operation Feed the Nation and Green Revolution Programmes of the late 1970s) failed to achieve significant increases in food production because of poor planning, monitoring, and coordination. Saouma (1981) indicated insufficient caloric intake among most rural peoples of Africa, especially in the Sahel zone. Government policies emphasize the development of export and cash crops, which were initially promoted by colonialists and, after attaining independence in the 1960s, by state parastatal and foreign companies, with a consequent increase in debts to banks and governments of Western nations. Agricultural research and extension were concentrated on cash and export crops even though millet and sorghum are by far the most abundant crops of the agricultural subsector. Strong (1982) notes that sub-Saharan Africa is the only area in the world in which the rate of per capita food production is falling (Fig. 1).

These phenomena have led to massive food shortages and the import of supplemental food. A typical example is Nigeria, where food imports rose from NGN 99.4 million in 1972 to NGN 1004.2 million in 1978 (2.58 Nigerian naira [NGN] = 1 United States dollar [USD]) (Table 1). Remedial efforts have failed, and the major victims of the food shortages are women, children, and the old and the sick. When food aid is given, the food habits of the people change. When people eat the food, they don't produce; dependence on food import and aid ensues, thereby worsening the African food crisis.

The Role of Yams

Yams (*Dioscorea* spp.) are pantropical plants with large reserves of food in their underground tubers. Species of yams have been grown in parts of West and Central Africa for millenia (Coursey 1967) and they are major carbohydrate sources for the inhabitants of these regions. In spite of this, not much has been done to improve yam cultivation; yams are still mainly cultivated by peasants with the hoe and cutlass, and have high labour requirements. Processing, storage, and marketing of the crop are poorly developed, and to avoid deterioration of harvested tubers, farmers accept giveaway prices from middlemen with low returns to investment and labour. These middlemen, in turn, extort high prices for yams from consumers. Thus, high consumer prices do not reflect farm incomes. Yam stocks last only 1 year after production.

The ethnocentric attachment to yam is very strong in areas of its production. In most parts of West Africa, yams are a symbol of wealth and influence in the community. This attachment has ironically

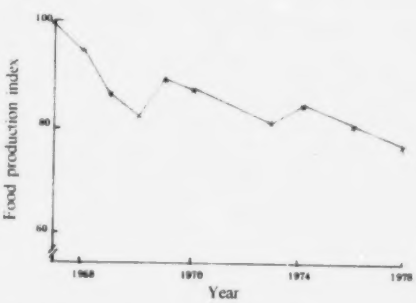

Fig. 1. *Index of food production per capita in sub-Saharan Africa (percentage of 1961–65 average). Source: U.S. Department of Agriculture, Indices of Agricultural Production.*

Table 2. Average production and consumption of yams in West Africa (1979–81).

Country	Production (t × 10^3)	Consumption (t × 10^3)	Per capita consumption (kg)
Burkina Faso	28	21	3.0
Cameroon	416	250	29.6
Central African Republic	192	144	62.7
Chad	163	131	29.4
Congo	13	12	7.8
Côte d'Ivoire	2142	1199	149.2
Benin	689	389	110.1
Gabon	80	52	94.9
Ghana	532	506	43.3
Guinea	77	69	13.8
Mali	10	9	1.3
Niger	0	0	0
Nigeria	17000	9717	126.0
Senegal	0	0	0
Sierra Leone	0	0	0
Togo	490	366	139.3
Zaire	183	152	5.4

Source: Food and Agriculture Organization computer printouts, and Phillips (1985).

Table 3. Additional food availability requirements (t × 10^3) from 1972 to 1985.

Country	Cereals	Root and tubers
Algeria	12687	185
Angola	214	745
Benin	127	330
Botswana	46	3
Burkina Faso	540	61
Chad	308	53
Ethiopia	1786	365
Guinea	259	226
Kenya	850	482
Liberia	769	1575
Mali	551	49
Mauritania	71	4
Mozambique	322	1128
Niger	398	96
Nigeria	3517	9890
Rwanda	80	452
Sao Tome and Principe	3	4
Somalia	208	18
Swaziland	27	4
Tanzania	649	1832
Uganda	354	588
Zaire	407	4700
Zambia	405	107

Source: Mazumdar (1980).

aggravated the food crisis by making producers fail to consider total food availability in the system, which would favour growing more crops, like cassava, whose food return to input ratio under existing technology is more favourable than that of yam. Although production and consumption of yam are high in most of West Africa (Table 2), shortages still exist. Based on relative shares of cereals and roots and tubers in the average national food availability of 23 African countries, Mazumdar (1980) estimated the incremental amount of cereals and of roots and tubers needed by each of the countries in 1985 (Table 3). From 1974 to 1984, yam production in six West African countries was related to the amount needed to satisfy domestic requirements assuming an annual population growth rate of 2.5% (Table 4). In Cameroon, Ghana, Nigeria, and Togo (responsible for over 85% of Africa's yam output), production lagged behind domestic requirements. In Benin and Côte d'Ivoire, however, production exceeded domestic requirements. A production deficit in Cameroon, Ghana, Nigeria, and Togo would make yams unavailable for relief needs in other parts of Africa during the period.

Since there is practically no import or export of roots and tubers in most African countries and there is no substantial carryover of stock over years (Mazumdar 1980), it would appear that yam has played an insignificant role in alleviating hunger and malnutrition in Africa. This seems to be partly due to insufficient production of the crop and partly due to its bulk and poor storability, making its transport and storage expensive. Yet, the development of yam will enable it to play a more significant role in lessening the African food crisis by supplying food energy to those countries whose caloric intake is deficient.

Because yam is mainly cultivated by peasants on smallholdings, its cultural role has become specialized and highly developed in some localities. For this reason, yields of *D. rotundata* can reach 33 kg/stand. In commercial agriculture, however, efforts are geared towards maximizing total yield with minimum attention to individual plants. Experimental yields above 40 t/ha have been obtained; even then, it is evident that the genetic potential for higher yields exists and that this could be exploited to increase the productivity of yam, giving it a significant role to play in meeting the food energy requirements of African peoples.

Yams are eaten mostly as a source of carbohydrate. Baquar et al. (1976) showed that some clones of *D. rotundata* and *D. dumetorum* have protein contents between 3.2 and 13.9% dry weight. Considering the variation existing in West Africa in these crops, it is possible that clones containing higher protein values could exist. In fact, some yams are superior to maize and rice in usable protein. Oke

Table 4. Yam production in six West African countries from 1974 to 1984 as a percentage of needed production assuming an annual population growth rate of 2.5%.

Year	Relative overall population	Benin	Cameroon	Côte d'Ivoire	Ghana	Nigeria	Togo
1974[a]	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1975	102.5	68.6	91.9	125.2	75.1	97.6	42.4
1976	105.1	113.3	90.2	118.6	84.3	97.4	43.6
1977	107.7	119.1	90.6	115.7	76.3	93.3	43.9
1978	110.4	136.4	100.4	108.5	75.2	91.0	46.8
1979	113.1	144.5	97.1	110.0	79.4	88.8	43.5
1980	115.7	131.6	97.0	112.0	78.0	89.7	41.7
1981	118.6	137.7	97.0	112.0	78.0	89.7	41.7
1982	121.5	134.5	96.5	106.8	53.8	87.9	48.0
1983	124.6	125.7	86.5	111.7	60.9	86.8	37.6
1984	127.7	127.7	88.0	110.4	53.5	94.1	38.7

Source: Food and Agriculture Organization production yearbooks.

[a]Yam production is set at 100% for 1974. Actual values are as follows ($t \times 10^3$): Benin, 435; Cameroon, 1065; Côte d'Ivoire, 1886; Ghana, 2350; Nigeria, 16817; Togo, 951.

(1967) reckoned that a yam meal could supply 100% of the energy and protein, 130% of the calcium, and 80% of the iron needs of an adult man. Most yams are also rich in phosphorus and some vitamins (thiamine, riboflavin, niacin, and ascorbic acid) (Eka 1985). Some of the less popular yams, such as *D. dumetorum*, and some wild yams are much richer in important amino acids than the more popular yams. Therefore, the genetic base exists for increasing the amino acid content of the more popular yams. Yam peels are rich in protein and carbohydrate (Eka 1985). They are traditionally fed to livestock (sheep and goats) in Africa.

With adequate moisture, yams can be grown in most of tropical Africa. Under rain-fed agriculture, which is practiced across Africa, yams are commonly grown in the forest and Guinea savanna zones of West and Central Africa (Fig. 2), where the annual rainfall exceeds 1000 mm. With irrigation, the Sudan–Sahelian zone of Africa, with its higher daily insolation (>250 J/cm^2), may also be suitable for yams. It is clear that current yam yields can easily be doubled through scientific research, the use of irrigation, and a shift of yam cultivation from the presently unsuitable areas to more appropriate regions.

Fig. 2. *Areas with a suitable climate for rain-fed yam production in Africa (shaded).*

Limitations to an Increased Role for Yams

Yam is a poorly developed crop. Its large-scale production and utilization is constrained by high production costs, unavailability of suitable fertilizers, herbicides, and pesticides, as well as a lack of appropriate implements for mechanized planting and harvesting. In future, yams must be consumed mostly as flours and flour-derived products. This will ease yam storage and transport, enhance national and international trade in yams, and enable the accumulation of surpluses from good seasons for use in lean years.

Processing yams into flour will boost the livestock industry because feedstuff ingredient production can utilize 10–15% of production. Nigeria produced 18.2×10^6 t of yams in 1982, and consumption of roots and tubers in Nigeria in 1972–1974 represented only 69% of the domestic production. For yams, a good proportion of the deficit must have been reserved for planting. If 50% of that yield were processed into flour before use, this would make 1.37×10^6 t of peels available as livestock feed.

The role of yam in helping to alleviate the African food crisis is promising; it has the potential to provide the majority of carbohydrates in the people's diet. Higher yields than cereal crops and the rarity of crop failures in yam cultivation imply that yams can supplement cereal foods in the Sudan and Sahelian zones of Africa. Moreover, present yam yields represent a small fraction of the potential, and research into yam agronomy, storage, and utilization is still in its infancy. When yam yields reach 50% of their potential, the carbohydrate supply will be sufficient for most of Africa, even from reduced hectarages. In turn, annual stocks of yams will increase and make the food supply more regular and prices more stable. What seems to be needed most are policies that favour food crop research and extension in most African countries. By this we mean changes that reflect proper relationships between the value of crops in the national economy and the amount of resource allocated to its development and production. Although there is no single dominant food crop in tropical Africa, such as rice in Asia or maize in Latin America, each crop should be developed to the extent of its socioeconomic advantage in the region and its potential to contribute to self-sufficiency and to export.

In Nigeria, for instance, we estimated that yam at NGN 400/t was worth over NGN 7280 million in 1984. If 0.1% of this value (NGN 7.28 million) is spent each year on yam research, development, and extension, we are certain that yam will be less costly to produce and yam products will better compete with other foods and feeds in domestic and foreign markets in Africa. This level of support is not expected to come from government sources alone; the private sector must also be encouraged to support research.

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EFFECT OF MULCHING MATERIAL AND PLANT DENSITY ON THE GROWTH, DEVELOPMENT, AND YIELD OF WHITE YAM MINISETTS

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Two experiments examined the effects of different mulching materials and plant populations on the growth and development of white yam (*Dioscorea rotundata*) minisetts. In experiment (expt.) I, six mulch treatments were used: (1) black and white polyethylene plastic mulch, white surface up; (2) black and white polyethylene plastic mulch, black surface up; (3) light-weight, black, polyethylene plastic; (4) rice straw; (5) no mulch, plants staked; (6) no mulch, no staking. For this experiment, the white yam cultivar TDr 131 was used. In expt. II, cv. TDr 131 and a second cultivar, TDr 179, were grown with and without polyethylene plastic mulch (white side up) at 20 000, 40 000, 60 000, and 80 000 plants/ha. Mean tuber size and total tuber yield were larger by over 50% in the white plastic mulch than in the traditional staking method and more than double those in the no-mulch, no-staking treatment (expt. I). The proportion of total tuber yield of marketable size (> 200 g) was similarly higher under the white plastic mulch. For both varieties (expt. II), tuber size decreased with increasing plant density with or without mulching. However, differences between mulched and unmulched treatments were generally larger at lower plant populations, indicating reduced benefits from mulching at higher plant densities. Plants in all treatments attained peak leaf area index (LAI) about 100 days after planting. Plants with the white surface plastic mulch maintained a higher LAI for most of the growing season. Soil temperatures were lowest under rice straw mulch. Overall, the white surface proved superior, being able to maintain a greater LAI and a longer leaf area duration.

Yam is traditionally propagated by means of the tuber. Whole "seed" tubers of 100–1500 g or larger tubers cut into approximately 200-g pieces are planted (Onwueme 1978; Okoli et al. 1982). In practice, this implies that over 20% of the annual yam production is reserved for planting.

The minisett technique was developed to overcome the shortage of "seed" yams. According to Okoli et al. (1982), a minisett is a sett less than one-quarter the minimum size (100 g) of yam sett often planted. Basically, the system entails cutting healthy "mother seed" yam into 20–25 g pieces. The pieces are immersed in a fungicide–insecticide suspension and planted into nursery beds to sprout for 3–4 weeks before being transplanted into the field.

During the past 3–4 years, the National Root Crops Research Institute, Umudike, Nigeria, together with the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, have jointly examined various aspects of the minisett technology to improve the system. One aspect that has been of particular interest to IITA has been the use of polyethylene plastic mulch in the production of "seed" yam.

In theory, the use of plastic mulch eliminates staking, preserves soil moisture and nutrients, and regulates soil temperature. Consequently, the overall growth, development, and yield may be better than that achieved without plastic mulch; however, quantitative evidence of the performance of crops from minisetts under plastic mulch was lacking. Moreover, the relative effects of other mulching materials, staking, and plant populations on the performance of the minisetts have received little research attention. This paper reports two experiments in which the performance of the minisetts was compared under different mulching materials, with and without staking, and with different plant populations.

MATERIALS AND METHODS

Two experiments were conducted in 1985 at IITA (about 30 km south of the northern limit of the lowland rainforest, with a bimodal rainfall pattern from April to July and from August to November). In experiment (expt.) I, six treatments were used: (1) black and white polyethylene plastic, white surface up; (2) black and white polyethylene plastic, black surface up; (3) light-weight, black, polyethylene plastic; (4) rice straw; (5) no mulch, plants

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Table 1. Percentage establishment of transplanted white yam minisetts as affected by different mulching materials.

Treatment	Weeks after transplanting		
	3	6	9
Polyethylene plastic			
Black surface up	65.7	83.4	90.1
White surface up	71.1	88.6	93.4
Light-weight, black plastic	64.2	85.4	90.2
Staking, no mulch	53.4	74.0	82.8
No staking, no mulch	51.0	70.8	85.8
Rice straw	69.4	84.9	89.3

staked; (6) no mulch, no staking. For all treatments, minisetts were transplanted onto ridges 1 m apart at 25-cm spacing on 10 m × 10 m plots in a randomized complete block design with four replicates. The white yam (*Dioscorea rotundata*) cultivar TDr 131 was used.

Minisetts were transplanted on 5 June 1985. Rice straw was applied (6 t/ha) at transplanting. For the staking treatment, plants were staked 6 weeks after transplanting. Plant growth was monitored using conventional growth-analysis techniques. Sampling was done at 21-day intervals beginning 60 days after transplanting and, on each sampling occasion, eight plants were taken from each treatment. Leaf area was measured with a portable area meter (LI-3000). Soil temperature for each treatment was measured twice daily at 0800 and 1500 using a bent stem thermometer set at 5-cm depth.

In expt. II, cv. TDr 131 and cv. TDr 179 were observed with plastic mulch (white surface up), without mulch, and at four plant densities. The minisetts were transplanted on 17 May 1985 on ridges 1 m apart with within-row spacings of 50, 25, and 15 cm or plant densities of 20 000, 40 000, and 60 000 plants/ha, respectively. Double rows of plants at 25 cm on the same ridge gave a plant density of 80 000 plants/ha. The treatments were carried out in a split split-plot design with three replicates in which the plastic-mulch and no-mulch treatments were the main plots; the two cultivars were assigned to subplots and the plant densities were assigned to subsubplots. For both experiments, weeds were removed as necessary.

Table 2. Percentage establishment of two cultivars of transplanted white yam minisetts as affected by polyethylene plastic mulch and plant density.

Plant density ($\times 10^3$/ha)	Weeks after transplanting					
	Mulch			No mulch		
	3	6	9	3	6	9
cv. TDr 131						
20	61.2	80.2	95.5	49.9	71.8	89.9
40	54.9	76.0	95.3	45.7	64.8	83.6
60	62.9	76.4	92.3	45.7	67.7	89.4
80	56.6	69.3	95.3	50.5	64.5	86.4
cv. TDr 179						
20	51.6	71.9	88.6	45.6	60.2	84.6
40	51.9	55.1	86.8	42.4	58.1	86.4
60	47.8	68.6	89.4	41.9	60.4	83.5
80	52.9	68.3	88.6	39.2	55.2	88.1

RESULTS

PLANT ESTABLISHMENT AND SOIL TEMPERATURE

In general, establishment (survival) of transplanted minisetts was slow (Tables 1 and 2), although better under mulch than without mulch. In expt. I, the mulched treatments reached 80% establishment within 6 weeks, whereas the staking and the no-mulch, no-staking treatments attained the same percentage establishment after 9 weeks. In expt. II, better establishment was obtained with cv. TDr 131, particularly under mulch.

Table 3. Effect of different mulching materials on soil temperature.[a]

Treatment	July	August	September	October	Mean
Polyethylene plastic					
Black surface up	36.08	30.56	31.14	33.70	32.87
White surface up	34.24	29.64	31.32	31.80	31.75
Light-weight, black plastic	35.42	30.30	33.94	33.50	33.29
Staking, no mulch	36.14	28.88	30.34	31.80	31.79
No staking, no mulch	—[b]	—	—	—	—
Rice straw	29.80	27.04	27.68	28.80	28.33
Bare soil	36.78	29.54	28.14	36.30	32.69

[a]Values are monthly means for 1500 reading during the main growing period (July–October).
[b]Measurements not taken.

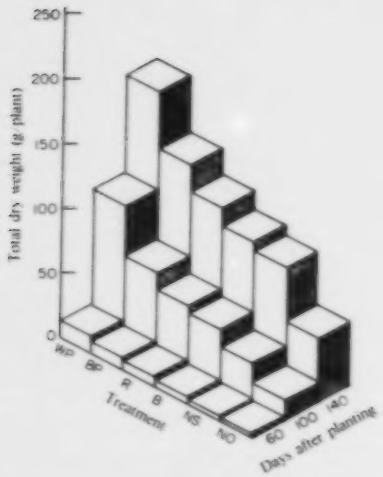

Fig. 1. *Effect of different mulching materials on dry matter production in white yam minisetts. Treatments: WP, polyethylene plastic, white surface up; BP, polyethylene plastic, black surface up; R, rice straw; B, light-weight, black, polyethylene plastic; NS, staking, no mulch; NO, no staking, no mulch.*

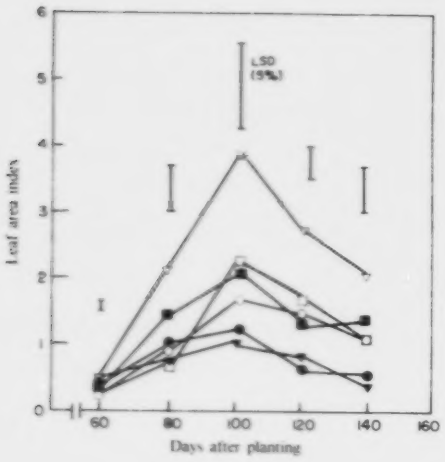

Fig. 2. *Effect of different mulching materials on the development of leaf area index in white yam minisetts. ▽, polyethylene plastic, white surface up; ■, polyethylene plastic, black surface up; □, rice straw; ○, light-weight, black, polyethylene plastic; ●, staking, no mulch; ▼, no staking, no mulch.*

Straw mulch reduced soil temperature more than did the other treatments or bare soil (Table 3). The straw also maintained a more uniform soil temperature throughout crop growth. These observations agree with those of Maurya and Lal (1981). In all the treatments, soil temperatures were higher during July.

Dry Matter Production and Leaf Area Index

Results of three of five samplings for dry matter production and leaf area index (LAI) in expt. 1 were used to construct Fig. 1. Plants under plastic mulch (white surface up) produced the highest dry weight of shoot, tuber, and roots per plant at each sampling date; the no-mulch treatment produced the lowest dry matter weight per plant. These differences were noticeable at first sampling and remained so throughout crop growth. For each treatment, maximum dry matter per plant was attained 140 days after transplanting.

The white surface plastic mulch maintained a significantly higher LAI throughout the crop growth period (Fig. 2). All treatments produced peak LAI about 100 days after transplanting; thereafter, the LAI declined rapidly. Under the white surface plastic mulch, peak LAI was three times that of the traditional staking method.

Table 4. Effects of different mulching materials on the yield of white yam minisetts.

Treatment	No. of tubers/ha	Tuber weight (g)	Tuber yield (t/ha)
Polethylene plastic			
White surface up	37330	605.82	22.18
Black surface up	36050	424.97	15.48
Rice straw	34300	517.79	17.87
Light-weight, black plastic	33790	415.48	14.15
Staking, no mulch	37160	399.93	14.88
No staking, no mulch	34150	312.89	10.65
F	0.500	9.17	8.852
LSD ($P = 0.05$)	12.792	101.59	3.938

Tuber Yield and Yield Components

In expt. 1, the number of tubers varied only slightly between treatments (Table 4). Tubers were most abundant (37 330/ha) with the white surface mulch and least abundant (33 790/ha) with the light-weight, black, plastic mulch; however, this difference is not significant. The white surface mulch gave a significantly larger mean tuber size and higher total tuber yield: 50% greater than in the traditional staking and more than double those values obtained from the no-mulch, no-staking treatment (Table 4).

Table 5. Effects of polyethylene plastic mulch and plant density on the yield of cultivars of white yam minisetts.

Plant density ($\times 10^3$/ha)	Polyethylene plastic mulch				No mulch			
	No. of tuber/ha	Tuber weight (g)	Tuber yield (t/ha)	% tubers >200 g	No. of tubers/ha	Tuber weight (g)	Tuber yield (t/ha)	% tubers >200 g
				cv. Tdr 131				
20	25000	680.23	17.36	94.47	23000	447.98	10.32	95.47
40	38300	555.91	21.30	88.28	38300	402.58	15.68	86.46
60	59500	334.36	19.93	73.93	65200	232.60	15.26	65.53
80	72200	330.89	25.90	81.76	63300	208.84	13.20	70.56
				cv. TDr 179				
20	19700	610.04	12.03	95.03	23100	316.33	7.98	69.53
40	39700	480.60	19.66	82.33	39000	303.43	12.25	66.70
60	57800	417.09	24.05	79.70	58800	264.56	15.54	47.43
80	68000	349.77	23.72	75.57	63900	259.24	15.14	70.83
LSD ($P = 0.05$)[a]	6.40	92.14	5.28	15.84				
LSD ($P = 0.05$)[b]	8.24	136.12	7.69	26.51				

[a]LSD to compare mulching treatments at a given plant population.
[b]LSD to compare plant population at a given main plot treatment or variety.

The rice straw treatment produced the second-best results.

In expt. II, the performance of the minisetts under plastic mulch (white surface up) was better than in the no-mulch treatment (Table 5). At each plant density, the average tuber size was more than 50% larger under plastic mulch than in the no-mulch treatment (Table 5). The highest tuber yield (25.9 t/ha from cv. TDr 131 at 60 000 plants/ha) nearly doubled in the yield of cv. TDr 131 without mulch. The proportion of tuber yield that was marketable (>200 g) was also greater with mulch than without mulch. For both cultivars, this proportion was 73.9 and 95% for high and low plant densities, respectively. In the no-mulch treatment, the proportion of marketable tubers was generally higher in cv. TDr 131 than in cv. TDr 179.

As expected, tuber size decreased with higher plant densities. In cv. TDr 131, the average tuber weight ranged from 680 g at 20 000 plant/ha to 330 g at 80 000 plants/ha under mulch. A similar trend occurred for the no-mulch treatment, except for cv. TDr 179, where tuber weight reductions with rising plant populations were consistently small and non-significant. Differences between mulched and no-mulch treatments were generally larger at the lower than at the higher plant populations.

DISCUSSION

This study showed that dry matter weight per plant and fresh tuber yield were much higher under the white surface plastic mulch. This was due to a higher LAI and a much longer leaf area duration than in the other treatments. While the cause of the higher LAI is not clear, the amount of leaf area available during tuber bulking largely determines yield in yam (Chapman 1965; Enyi 1972a,b). The higher yield from white surface plastic mulch may, therefore, relate to the higher LAI and longer leaf area duration, which must have ensured higher bulking rate for a longer period. Furthermore, white surfaces (as of the plastic mulch) reflect light (albedo effect), which could have improved light interception by plants grown under the white polyethylene plastic mulch.

Overall, the LAIs obtained in these trials were low for yam, partly because tuber initiation was early (6–7 weeks after transplanting) when LAI was still low. Intraplant competition between developing tuber and shoot for assimilates restricted leaf area development. Yams planted in the field initiate tubers 12–13 weeks after emergence (Sobulo 1972; Onwueme 1978), thus allowing for sufficient leaf area development before tuber bulking. This argument implies that seed yam yields in these trials are only a fraction of their potential.

In expt. II, tuber size decreased with increasing plant density; however, even at 80 000 plants/ha, tubers above 300 g under plastic mulch were obtained. There were larger differences in tuber size between mulch and no-mulch treatments at lower than at higher plant populations. This indicates reduced benefits from mulching, with regards to tuber size, as plant populations increase. Since tuber size and number of tubers influence seed yam yield, these aspects require more research.

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AXILLARY BUDS AND VEGETATIVE PROPAGATION OF *DIOSCOREA*

F.I.O. NWOKE[1]

Dioscorea alata L. and *Dioscorea dumetorum* Pax. have five buds (one primary and four accessory, or secondary, axillary buds) in each leaf axil. *Dioscorea rotundata* Poir. and *Dioscorea cayenensis* Lam. have four buds and *Dioscorea bulbifera* L. has three buds and a "bulbil primordium" in each leaf axil. All five species have the descending type of multiple axillary bud arrangement. Organ regeneration in stem cuttings of *D. bulbifera* planted in soil began with a whitish tuberous growth, also known as the primary nodal complex, which was formed from a proliferation of the cells of the "bulbil primordium" as well as the cells at the base of the accessory axillary buds. The internal structure of this tuberous organ resembles a yam tuber or aerial bulbil in having loosely packed inner parenchymatous cells and a cortex of tightly packed, small, parenchymatous cells surrounded by an epidermis. Adventitious roots and shoot primordia arise near the cortex of the tuberous organ. Despite the formation of these adventitious shoot primordia, the second accessory bud usually grew to become the aerial shoot.

Over the centuries, yams have been vegetatively propagated by means of seed tubers or tuber setts (Coursey 1967). Sadik and Okereke (1975) demonstrated the possibility of propagating yams by sexual seed; however, this method is still of limited application. Propagation of yams by leaf or stem cutting has also been demonstrated (Correll et al. 1955; Njoku 1963; Martin and Gaskins 1968; Cabanillas and Martin 1978). Indeed, Vander Zaag and Fox (1981) have shown that stem cuttings are suitable for field production of ware yams in *Dioscorea alata* L. About 3–8 weeks after planting, a stem cutting, roots, and then new shoot and tuber are formed in the leaf axil (Njoku 1963). This paper describes the anatomy of the leaf axil of five species of *Dioscorea: D. rotundata* Poir., *D. cayenensis* Lam., *D. alata* L., *D. dumetorum* Pax., and *D. bulbifera* L. The organ regeneration in leaf axils of *D. bulbifera* stem cuttings is also discussed.

MATERIALS AND METHODS

Ten yam nodes each of *D. rotundata*, *D. cayenensis*, *D. alata*, *D. dumetorum*, and *D. bulbifera* were obtained from the lower 20 nodes of 5–8 week old plants and fixed in formalin – alcohol – acetic acid (FAA).

For studying organ regeneration in stem cuttings of *D. bulbifera*, 30 stem cuttings, consisting of stem branches, several nodes, and leaves, were taken from 5–8 week old plants. The lowest node and the lower end of the petioles were then buried in a moist mixture of soil, heap compost, and dung (3:1:0.1, by volume) contained in black plastic bags (20 × 12 cm, 0.04 mm thick) placed in the shade. Stem branches containing several nodes were used as cuttings instead of the usual one-node stem cuttings used by previous workers (Correll et al. 1955; Njoku 1963; Martin and Gaskins 1968; Cabanillas and Martin 1978), because studies with stem cuttings containing varying numbers of nodes and leaves have shown that two or more node cuttings produced more roots, a larger shoot, and a heavier tuber, than one-node cuttings (Okonkwo et al. 1973). Three samples of 10 cuttings were made at weekly intervals during which the lowest node of each cutting was cut off, washed, and fixed in FAA.

Preserved tissues were dehydrated through a tertiary butanol series and embedded in wax (Sass 1958). Serial longitudinal sections, 10 μm thick, were cut through the leaf axil using an American Optical 820 rotary microtome. The sections were stained with safranin and fast green and mounted in Canada balsam.

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RESULTS

AXILLARY AND ACCESSORY BUDS

Figure 1A is a longitudinal section through the leaf axil of *D. dumetorum* showing the base of an axillary branch (produced by the growth of the axillary bud) nearest the stem and four dormant accessory (secondary) buds between it and the petiole. All the buds are arranged in a radial file. Figure 1B shows that *D. alata* also has an axillary branch and four dormant accessory buds. The median longitudinal section through the leaf axil of *D. cayenensis* (Fig. 1C) shows a short axillary branch and three dormant accessory buds. Likewise, the leaf axil of *D. rotundata* possesses a total of four buds, but, in this figure, only part of the base of the axillary branch and three accessory buds between it and the petiole are visible (Fig. 1D). The median section through the leaf axil of 5-week-old *D. bulbifera* (Fig. 2A) shows the presence of an axillary branch and two accessory buds as well as a "bulbil primordium" between the second accessory bud and the petiole. The term "bulbil primordium" was used by earlier investigators (Okonkwo et al. 1973) to describe a hump of meristematic tissue between the accessory buds and the petiole that presumably gave rise to the aerial bulbil in *D. bulbifera*.

ORGAN REGENERATION FROM STEM CUTTINGS

Njoku (1963) had shown that, irrespective of the yam species, a stem cutting lifted from the soil 1–2 weeks after planting formed a small whitish body, known also as the primary nodal complex (Ferguson 1972), within the leaf axil. Figure 1E shows this whitish body bearing two prominent adventitious roots in the leaf axil of *D. bulbifera*. At that stage, a longitudinal section through the leaf axil of *D. bulbifera* stem cutting (Fig. 2C) shows that the whitish body lies between the axillary branch and the petiole and has a definite tuberous structure: an epidermis surrounding a ground tissue of parenchymatous cells. The bulbil primordium (Fig. 2A) is no longer present between the accessory buds and the petiole, rather, its position is now occupied by the tuberous organ, indicating that the latter was derived from the bulbil primordium through cell divisions and enlargement. Apparently, tissues at the base of the two accessory buds were also involved in cell proliferations to form the tuberous organ, hence the first and the second accessory buds have become lifted to occupy new positions at the side and dorsal end of the tuberous organ, respectively (Figs. 2C, 2E). The dorsal end of the tuberous organ is the end opposite the point of its attachment to the leaf axil. At the same time, the tuberous organ grows to envelop the second accessory bud (Figs. 2C, 2E). Below the epidermis, the parenchymatous ground tissue may be distinguished into a cortex consisting of 15–20 layers of small tightly packed parenchyma cells; this is followed by an inner ground tissue of large but loosely packed parenchymatous cells (Fig. 2E). Numerous tannin cells and idioblasts containing raphide bundles are found scattered within both the cortex and the inner parenchymatous tissue (Figs. 2C, 2E). Thus, the internal structure of the tuberous organ is generally similar to that of the yam tuber or bulbil.

Figure 2B is the tangential longitudinal section through the ventral end of the tuberous organ showing the primordium of one of the two prominent roots (Fig. 1E) originating from that part of the inner parenchymatous ground tissue adjoining the cortex. The root primordium, which already has developed connecting vascular strands, can be seen as it pushes through the cortex of the tuberous organ and through tissues at the base of the axillary branch (Fig. 2B). At the same time, the second accessory bud situated at the dorsal end of the tuberous organ (Fig. 2E) increases in size by cell division. Although other shoot meristems are formed (Fig. 2E), it is the second accessory bud that grows into a shoot (Fig. 2F). More adventitious roots are produced and the origin of one of these roots is shown in Fig. 2D. At this stage, the epidermis of the enlarged tuberous organ was replaced by layers of cork cells.

DISCUSSION

The presence of multiple axillary buds has been reported in some *Dioscorea* species (Burkill 1960; Rao and Tan 1976; Sharma 1976). Sharma (1976) observed one axillary and two accessory buds in *D. glabra*, while Rao and Tan (1976) found one axillary and three accessory buds in *D. sansibarensis*, just as this study has found in both *D. rotundata* and *D. cayenensis*. The finding that *D. alata* and *D. dumetorum* possess one axillary and as many as four accessory buds each is noteworthy as this appears to be the highest number of accessory buds yet recorded among *Dioscorea* species. The multiple buds of all these species belong to the descending type of bud arrangement because the axillary bud is nearest the stem; the accessory buds are arranged radially between it and the petiole (Standt 1935; Keep 1969).

During vegetative growth, the axillary bud usually develops into a lateral branch; however, during the reproductive stage, the axillary bud and some accessory buds are usually transformed into inflorescence branches, as was shown for *D. bulbifera*

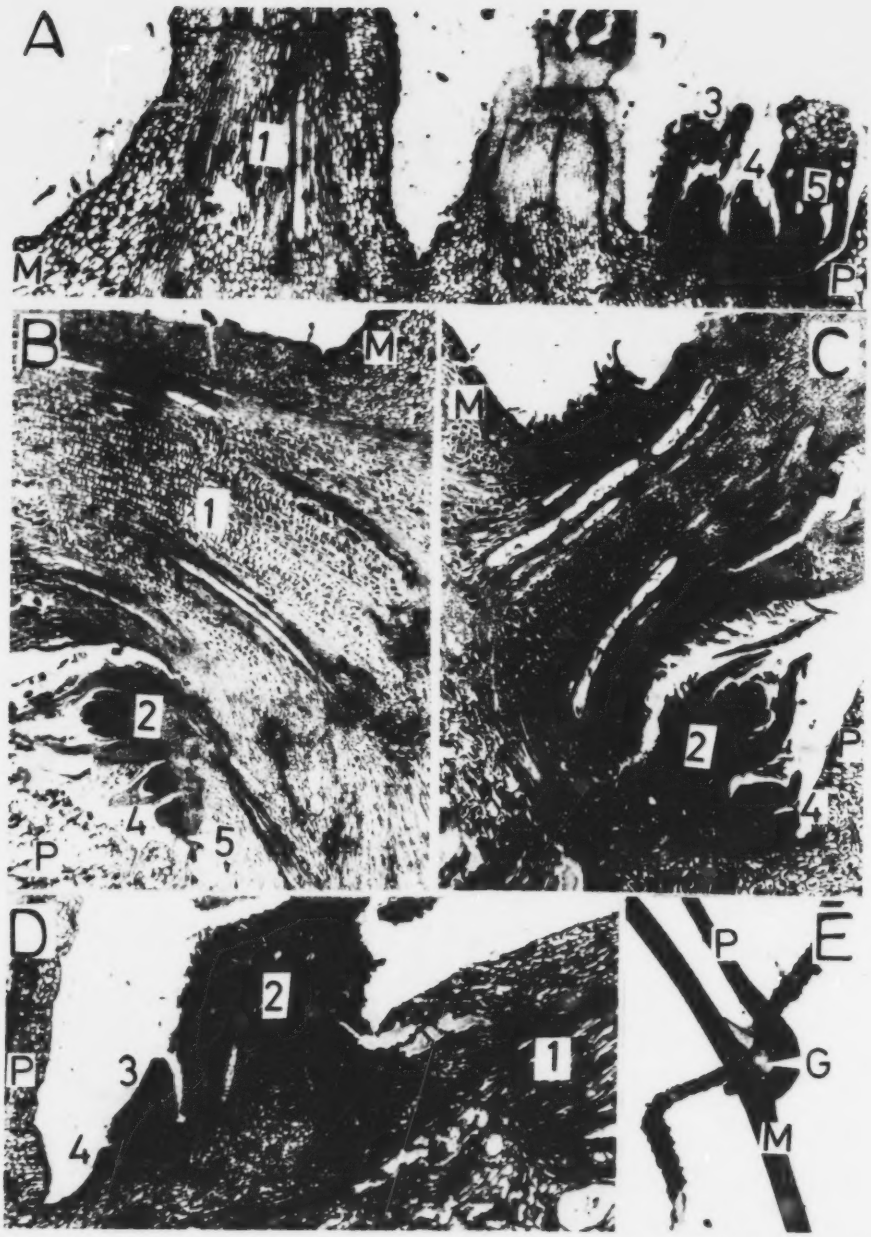

Fig. 1. *Longitudinal sections through the leaf axil of* Dioscorea *species showing axillary branches and varying numbers of accessory buds: (A)* D. dumetorum, × *46; (B)* D. alata, × *46; (C)* D. cayenensis, × *46; (D)* D. rotundata × *46; (E) 2-week-old* D. bulbifera *stem cutting. Abbreviations: 1, axillary bud (branch); 2, first accessory bud; 3, second accessory bud; 4, third accessory bud; 5, fouth accessory bud; B, bulbil primordium; C, cortex; E, epidermis; G, tuberous organ; K, cork cells; M, stem; N, inner ground tissue; P, petiole; R, root (root primordium); S, shoot (shoot primordium).*

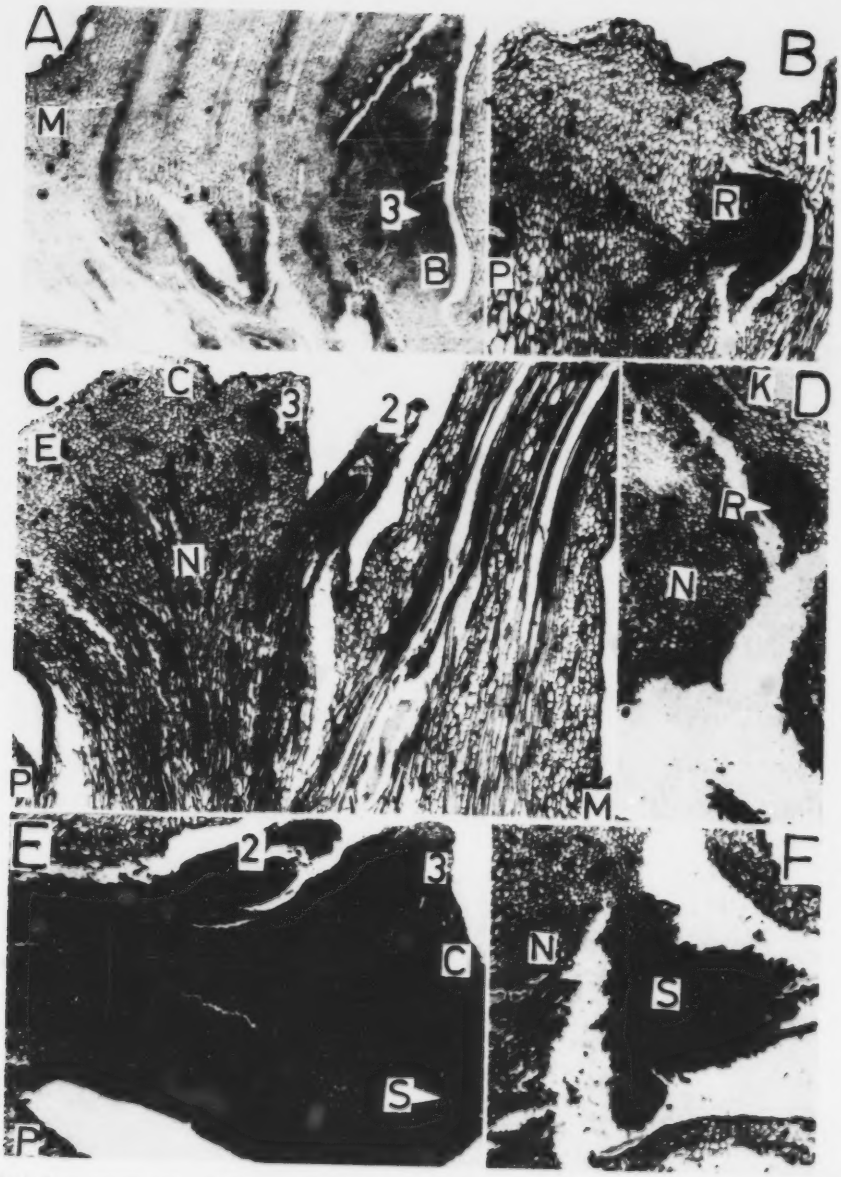

Fig. 2. *(A) Longitudinal section (LS) through a leaf axil of* D. bulbifera *showing an axillary branch and accessory buds. × 46. (B) Tangential longitudinal section (TLS) through the ventral end of the tuberous organ showing the origin of the root primordium. × 46. (C) LS through a leaf axil of a 1-week-old* D. bulbifera *stem cutting showing the internal structure of the tuberous organ. × 46. (D) TLS through the dorsal end of the tuberous organ of a* D. bulbifera *stem cutting showing the origin of the adventitious root primordium from the tissues of the inner ground tissue adjoining the cortex. × 46. (E) LS through the tuberous organ of a 2-week old cutting showing the formation of the adventitious shoot primordium × 46. (F) Same as Fig. 2E, except that the section passes through a new shoot formed by the resumed growth of the secondary accessory bud. × 46. For abbreviations, see caption to Fig. 1.*

(Okonkwo et al. 1973). Thus, although most edible yams have a reduced ability for sexual reproduction, as is common with plants that have been vegetatively propagated over long periods of evolutionary time, it appears that the development of many accessory buds in these *Dioscorea* species was originally a reproductive strategy, as in *Rubus idaeus* (Keep 1969), to ensure an adequate production of flowers. In parent plants, from which stem cuttings were taken, growth of accessory buds was suppressed during the vegetative phase by apical dominance involving not only the apical bud of the main stem but also buds of the axillary branch. Thus, a resumption in growth of the second accessory bud to form the shoot of *D. bulbifera* stem cutting indicates that the normal apical dominance prevailing among the axillary and accessory buds has become disorganized in favour of a new apical dominance within the tuberous organ centred around the secondary accessory bud.

The present study shows that the tuberous organ in *D. bulbifera* arose from proliferations of both the bulbil primordium and the basal cells of the accessory buds. Similar studies with other species of *Dioscorea* show that the tuberous organ is probably formed from an intercalary meristem as well as from the cells at the base of the accessory buds, but these results will be reported elsewhere.

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INVOLVEMENT OF DAY LENGTH IN THE TUBERIZATION OF *DIOSCOREA ROTUNDATA* MINISETTS UNDER NSUKKA CONDITIONS

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Dioscorea rotundata (cv. Nwaopoko) minisetts were presprouted for 10 weeks under Nsukka conditions. From the 6th week, the plants were serially subjected to short-day (10 h light – 14 h dark) and long-day (16 h light – 8 h dark) conditions in a greenhouse and were sampled weekly for tuberization. Despite the varied time of tuberization among plants, short days induced more tuberization at the early growth phase than did long days. This observation was supported when less tuberization was obtained when light breaks were applied in the middle of the long dark period. The promotive effect of short days on tuberization tended to diminish with the age of the plants prior to their exposure to the short-day treatment.

Although alternative modes of yam propagation have been reported, propagation through the tuber as seed yams, setts, or bulbils remains the most common method. The continued use of tubers indicates a need to exploit factors that enhance early tuberization and, hence, extend the period of tuber bulking in the field.

Njoku (1963) and Okezie (1981) have shown that tuber growth in *Dioscorea alata* from vine cuttings and *Dioscorea rotundata* from true seeds is under photoperiodic control, with short days promoting tuber dry weight and long days limiting it. Okonkwo (1985) pointed out that research on the effect of photoperiod on yam tuber initiation is lacking. Such work has been done for potato (Garner and Allard 1923) and cassava (Bolhuis 1966; Lowe et al. 1976).

The minisett technique (Okoli et al. 1982) offers great potential for the rapid multiplication of seed yam. Environmental factors that enhance tuberization could help improve this technique. This paper examines the influence of day length on the tuberization of *D. rotundata* cv. Nwaopoko plants from minisetts.

MATERIALS AND METHODS

Minisetts of *D. rotundata* cv. Nwaopoko were prepared according to Okoli et al. (1982) and were only taken from the head region of the tubers to ensure better sprouting. To protect against rotting, minisetts were dusted with Aldrex T (10 g to 150 minisetts) and spread to air dry on a floor for about 24 h (Iwueke et al. 1983) before presprouting. Minisetts of 25 ± 2 g were presprouted for 10 weeks in nursery boxes containing sawdust in a greenhouse with a mean temperature of 27 ± 2°C and a relative humidity of 68%. The sawdust was watered sparingly and the boxes were covered with a polythene sheet to improve moisture retention.

Sprouting started by the 4th week of presprouting, and from the 6th week, when many of the propagules had developed at least one fully expanded leaf, to the 10th week, uniformly growing, nontuberizing minisetts were transferred singly into a soil–dung mixture in large black plastic planting bags placed on wooden frames in the greenhouse. The bags containing the propagules were segregated into three treatments: 10 h light – 14 h dark; 16 h light – 8 h dark; and 10 h light – 14 h dark with a light break in the middle of the 14-h dark period.

A light period of 10 h was achieved under natural daylight by covering the plants with a hood of thick black cloth over a wooden frame from 1800 to 0800. The 16-h light period was achieved by extending the natural daylight with four cool-white fluorescent tubes (Quickstart BG Tropical Day-light, 6500 klx) controlled by an automatic plug-in time switch, producing a light intensity of 600 lx at plant level between 1800 and 2200 and again between 0600 and 0800 the following morning to take care of the differences in time of sunset and sunrise. A light break in the middle of the 14-h dark period was achieved by manually switching on a light from two fluorescent tubes installed in one of the short-day chambers at 0100 every morning for 10 min, providing about 200 lx intensity at plant level. The plants were then left to grow to maturity.

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For the various determinations, 10–20 plants per treatment were sampled, and each plant served as a replicate. To monitor the time of tuber initiation, 10–15 plants were harvested daily under each treatment and records were kept on the number of days to tuberization. The effect of day length on plant tuberization was determined by harvesting 15–20 plants per treatment weekly; only plants that were 6 weeks old at the time of exposure to the different day lengths were collected. The effect of day length on the pattern of assimilate partitioning to the various organs was also determined for plants that were 6 weeks old at the time of exposure to short- and long-day treatments, and from the time of tuber initiation. Ten plants were harvested from each treatment, and the leaves, vines, roots and tuber of each plant were separately partitioned into envelopes and oven-dried to a constant weight at 80°C for 48 h. Thereafter, measurements were taken of the average weight of each plant part per treatment.

RESULTS

Tuberization was noticed earlier in plants exposed to short days than in those exposed to long days among young plants (6–7 week old propagules); the reverse was true in older plants (8–10 week old propagules) (Fig. 1). Also, at the time of photoperiod treatment, older plants tuberized earlier. Plants exposed to short days with a light break in the middle of the 14-h dark period tuberized at the same rate as those plants under long days, suggesting a nullification of the tuberizing effect of short days by the light break.

Better induction of tuberization under short days occurred for only the first 4 weeks of growth. After tuberization, long days induced tuberization better than short days; by the 8th week, when 100% tuberization had been achieved under long days, 80% tuberization had been achieved under short days (Fig. 2). Also, plants under short days with a light break in the middle of the 14-h dark period showed the same pattern of tuberization as did those plants under long days.

Figure 3 shows that there was significantly ($P = 0.05$) more shoot growth under long days than under short days from the 8th week of growth under the various day lengths. Although root growth terminated early under both day lengths, long days tended to support more root growth than did short days. From the time tuber was initiated to the 6th week of growth, however, there was greater tuberization under short days; thereafter, as the plants got older, there was greater tuberization under long days. Interestingly, there was no significant difference between the total plant dry weights under both day lengths.

DISCUSSION

The promotive effects of short days on tuberization in young *D. rotundata* plants raised from minisetts as found in this study is consistent with earlier

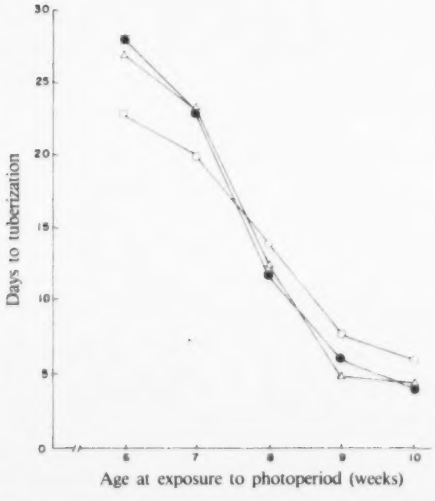

Fig. 1. *The effect of age of* Dioscorea rotundata *cv. Nwaopoko propagules raised from minisetts exposed to short days (○), long days (●), or short days with a light break (△) on the number of da s to tuberization.*

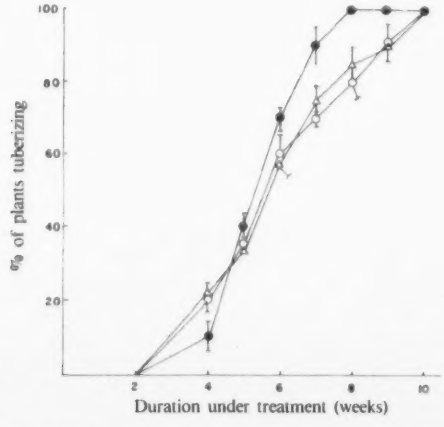

Fig. 2. *Time course (percentage tuberization) of* Dioscorea rotundata *cv. Nwaopoko plants raised from minisetts as affected by short days (○), long days (●), and short days with a light break (△).*

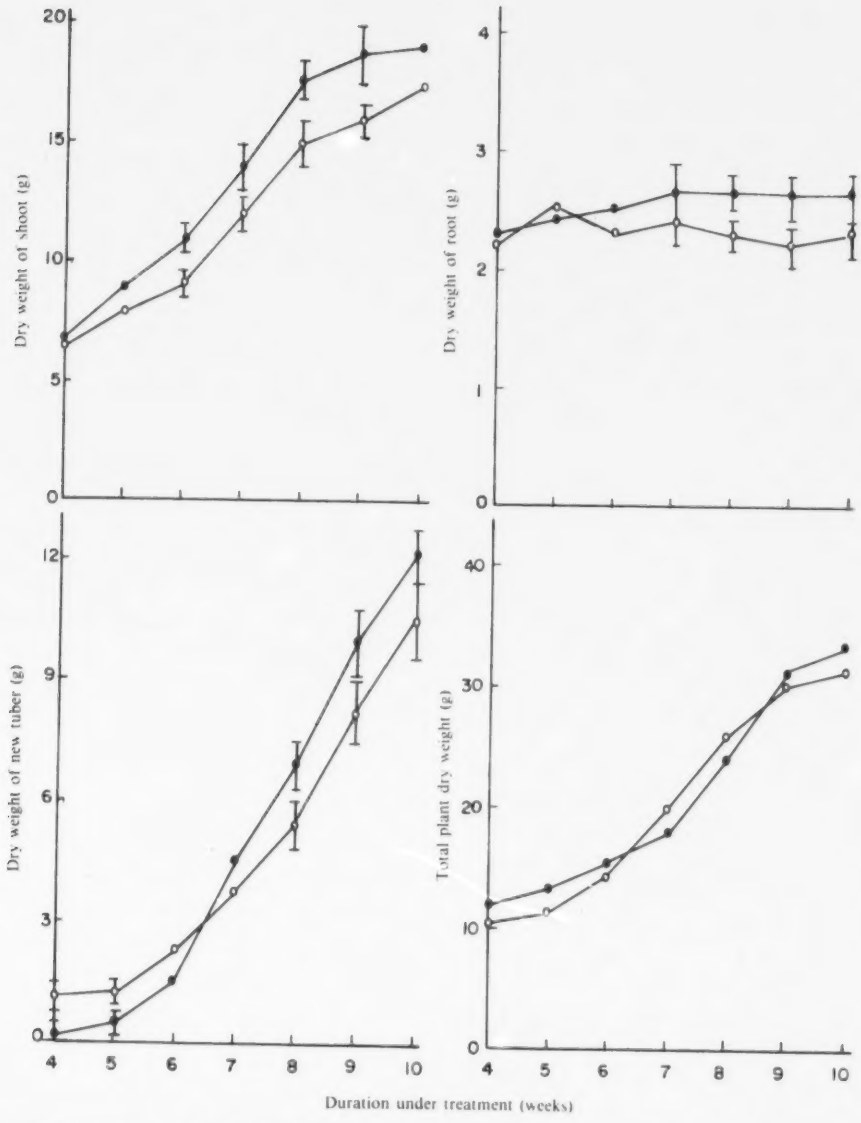
Dry weight of shoot (g)
Dry weight of root (g)
Dry weight of new tuber (g)
Total plant dry weight (g)
Duration under treatment (weeks)

Fig. 3. *Time course (dry weights of various organs) of* Dioscorea rotundata *cv. Nwaopoko plants raised from minisetts as affected by short days (○) and long days (●).*

results on *D. rotundata* raised from seed (Okezie 1981) and *D. alata* raised from vine cuttings (Njoku 1963). Similar results have also been reported for potato (Garner and Allard 1923; Chapman 1958) and cassava (Bolhuis 1966; Lowe et al. 1976).

The reduction in the number of days to tuber initiation under short days relative to long days, based on the daily sampling of plants in this study, would suggest that, apart from tuber bulking, short days also enhanced earlier tuber initiation, especially

among young propagules that were 6–7 weeks old at photoperiod exposure. That a light break in the middle of the 14-h dark period nullified the promotive effect of short days supports an involvement of short days in the enhancement of tuberization. Wareing (1973) has suggested that tuberization is under hormonal control and that there may well be a specific tuber-initiating hormone. Kumar and Wareing (1973) showed the existence and movement of a specific tuberization stimulus in *Solanum andigena*; although no tuber-forming hormone has yet been identified in yams (Okonkwo 1985), this could be the case for the short-day, young *D. rotundata* plants in this study. Such a factor would accumulate more in the leaves of young plants under short days or induce the development of new tubers by direct translocence of material from the mother tuber in a manner similar to tubers under moisture stress (Onwueme 1975).

In the older propagules (8–10 weeks old at photoperiod treatment), however, short days did not enhance tuberization. This was probably because leaf development reached a stage where contribution of photosynthates to tuberization suppressed the effect of the stimulus that enhances tuberization under short days. This agrees with studies in which tuberization occurred by the 9th week (Nwoke et al. 1984), between the 8th and the 10th week (Njoku et al. 1984), or by the 10th week (Okezie et al. 1986). Therefore, in older plants, the internal mechanism that ensures tuberization before day-length treatment might have suppressed the mechanism that enhances tuberization under short-day conditions.

Greater enhancement of tuberization by short days than long days was only apparent within the first 3 weeks from the time of tuber initiation, when tuber dry weight was significantly higher ($P = 0.05$) under short days. The inability to maintain this trend might be due to superior shoot growth under long days. Consequently, with the development of a full canopy, excess photosynthates produced under long days led to a greater tuberization at this later phase of growth than did the photoperiodic effect of short days. Similar findings have been reported for *D. rotundata* plants raised from seed (Okezie 1981).

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Factors limiting yam production in Benin

Y.M. Gbedolo[1]

Yams are one of the most important food crops in Benin and are grown mainly in the northern regions. This paper outlines and suggests solutions to certain major factors that presently limit yam production, attempts to increase production, and contributions that could be made by agricultural research. One of the most important factors limiting yam yield is the lack of improved cultivars and agricultural techniques suitable for existing environmental conditions. Research into this problem could improve production and solve problems of soil fertility. It is also important to consider problems related to yam storage and marketing (harvesting, distribution, and sales in urban areas).

Yams are one of the most important food crops in Benin. They are grown mainly in the northern regions (Borgou–Atacora) and in the north of the central province of Zou, where it plays an important social and economic role. Growing yams is an activity that integrates all the mores and traditions of the population of northern Benin to the extent that, in this area, it is possible to speak of a genuine yam culture. Yams are traditionally served during all major ceremonies, offered as gifts to honourable guests, and represent the central point of all ritual activities. However, yam production has declined over the last few years. This decline has been due to various technical, economic, and social factors and can be easily explained on the basis of the difficulties encountered not only in growing yams but also in researching the crop.

Technical Difficulties

Soil Fertility

Physical Fertility

Yams are very demanding plants. Generally, they are the first crop in a rotational growing plan and are planted in very rich soils that have been thoroughly prepared and carefully ridged. This requires a substantial amount of labour; however, because of the exodus from rural areas, labour is becoming increasingly scarce, tending to increase production costs considerably.

Soil preparation causes a significant amount of caking, which, in turn, leads to soil degradation. This phenomenon, which starts immediately after ridging, is due to the intense evaporation produced by the harmattan wind, especially in March and April: a result of alternating moist and drought conditions produced by early rains and high temperatures. Observations carried out in northern Benin have established that soil caking has an adverse effect on yam cropping because it considerably increases the heat conductivity of the medium, thereby increasing the rotting of the cuttings planted, and because it offers considerable resistance to the emergence of young shoots and, thus, extends the sprouting period and delays growth.

Under present conditions, the most effective solution to this problem is to avoid any large-scale mechanization of yam farming and to attempt to integrate yam into an appropriate rotation system to allow it to remain undisturbed. Nevertheless, draft animals, which cause less soil deterioration, could be used. Sprouting and, consequently, planting should be delayed until the first rains. This delay is necessary for phytosanitary reasons (nematodes).

Chemical Fertility

The many tests with mineral fertilizers that have been carried out in northern Benin have rarely produced positive results. Negative results have often been obtained, particularly with nitrogen fertilizers (abundant vegetation and low organoleptic quality of the tubers). Organic fertilizers, however, have always produced promising results. Nevertheless, since they are relatively difficult to obtain, it is impossible to use organic fertilizer in a rural environment.

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Table 1. Effect of planting density on the production and yield of two varieties of yam.

Yam variety	Spacing (m)	Plant density (no./ha)	Production (kg/ridge)	Yield (yams/ha)
D. cayenensis var.				
Terkokonou	1.2 × 1.2	6944 (100)[a]	2.52 (100)	17.50 (100)
	1.6 × 1.6	3906 (56)	3.70 (147)	14.45 (83)
	2.4 × 2.4	1736 (25)	5.71 (227)	9.97 (57)
D. rotundata var.				
Singou	1.2 × 1.2	6944 (100)	1.95 (100)	13.55 (100)
	1.6 × 1.6	3906 (56)	2.55 (131)	9.96 (74)
	2.4 × 2.4	1736 (25)	4.62 (237)	8.02 (59)

[a]Values in parentheses are relative percentages.

The use of recurrent artificial fallow cycles is undoubtedly the simplest method that can be used to restructure the soil prior to planting. In terms of chemical fertility, taking advantage of the residual effects of previous crops in a continuous cultivation system could maintain fertility rates at an acceptable level and facilitate high yam yields. In other words, an in-depth study of crops planted before yams could provide a satisfactory solution to the problem of soil fertility.

Agricultural Techniques

In a region where yams are the mainstay of the diet, success in integrating this plant into a continuous cultivation system will depend upon convincing the farmers that the new techniques will be more productive than the traditional methods. It is easy to understand the reservations expressed by farmers about attempts by the Directorate of Agronomic Research to change agricultural techniques.

For the farmer, there are three important objectives:

- production of *Dioscorea rotundata* as early as possible;
- good tuber size (large tubers have better marketing qualities); and
- high yield at low cost.

Decreased planting densities and staking both help in meeting these objectives.

Planting Density

As long as soil fertility is not too low, decreasing planting density (increasing ridge size) can result in higher yields. Thus, farmers can produce normal-sized tubers (with good marketing quality) and keep production at a sufficient level to meet their needs (Table 1).

Staking

The effectiveness of staking yams is well known; however, because of the labour required, it is not done in the traditional system. Experience has shown that varieties of *D. rotundata* respond best to staking and that it is mainly during the second harvest (production of seed-bearing plants) that the technique is most effective: after the first harvest, the plants require a higher photosynthetic activity to strike (Table 2). In most cases, staking is economically advantageous; however, less expensive methods of supporting the plants up to a height of 2 m must be found.

Planting Materials

In the traditional system, planting materials are often difficult to obtain, costly, and of mediocre quality. In general, the crop is planted using pieces of yam tubers. This planting method, which deprives the farmer of a good part of his or her production (about 20–25%), has disadvantages:

- The tubers used have been stored for 4–6 months and have undergone severe physiological deterioration leading to a decrease in harvest yield; and
- After planting, the yam pieces are attacked by fungi and other soil microorganisms.

Under these conditions, the best planting materials to use are whole, small, healthy tubers weighing 450–600 g. These tubers sprout well in the field and give an improved yield. Thus, a technology that would produce this type of tuber faster would effectively solve the planting materials problem.

Weed and Nematode Problems

Research has shown that the upkeep of a yam crop in a continuous cultivation system is more labour intensive than is the case with other crops (Table 3). The African farmer is aware of this problem. Thus, to change ancestral agricultural methods, the farmer must be offered an alternative that will not increase labour costs.

Table 2. Effect of staking on two varieties of yam.

Yam variety	Yield (kg/ha)		Change (%)
	No staking	Staking	
D. cayenensis var. Terkokonou	16.78	24.95	46
D. rotundata var. Agogo			
First harvest	8.32	15.40	85
Second harvest	2.29	7.54	229
Total yield	10.61	22.94	116

Contrary to other crops, where the use of selective herbicides allows the crop to become established by delaying competition by weeds during the entire growth period, in the case of yams, a single herbicide treatment is often insufficient to control weeds. Nematodes are dangerous to yam crops, especially in a continuous rotation system. When yams are not grown on cleared land, they are quickly attacked by nematodes. This can considerably affect yield by endangering plant sprouting (rotting of the cuttings in the soil) and decreasing the vegetative strength of the plants.

The use of recurrent artificial fallow cycles may be one of the most effective and least expensive solutions to the problems of weeds and nematodes. *Andropogon gayanus* is the most suitable species for artificial fallowing. After the sorghum grown at the end of the rotation, *A. gayanus* is easy to grow, resistant to brush fires, and does not present any difficulties as far as seed supply is concerned. In the case of nematodes, staggering the planting dates is an effective solution.

Storage

The food shortage in the developing world is so severe, especially in sub-Saharan Africa, that any means to increase agricultural production and limit postharvest losses is welcome. Traditional yam-storage methods were designed within the framework of a self-sufficient economy and have ensured the subsistence of populations for generations. These traditional storage methods are based essentially on the capacity of various yam varieties to resist rot. In this respect, the best species are *D. alata* and *D. dumetorum*. Among the *D. cayenensis* varieties, dry season crops keep better than yams that produce two crops.

According to surveys on postharvest technologies carried out in Benin, almost 85% of the rural population consumes yams that they have produced themselves. Taking into account these new data and observations, efforts, which should be maintained and developed, are being made to reduce postharvest losses. Thus, agricultural research should improve traditional storage methods.

Table 3. Upkeep costs of various crops and crop combinations in a continuous cultivation system in Benin.

Crop	Daily labour requirement (no./ha)	Total cost (XOF × 10^3/ha)[a]
Corn	103	56.65
Sorghum	115	63.25
Peanut	126	69.30
Corn–sorghum	145	77.55
Cassava	152	83.60
Cotton	170	93.50
Yam	269	147.95
Yam–niébé	280	154.00

Source: SAFGRAD (1985).

[a]In March 1987, 309 CFA francs BCEAO (Banque Centrale des États de l'Afrique de l'Ouest) (XOF) = 1 United States dollar (USD).

Economic and Social Problems

Economic Problems

Characteristics of the Trading Channels

In Benin, the marketing of yams, like that of tropical starchy foods in general, is carried out by traditional traders. The so-called "modern" marketing sector is not interested in such products. As far as the public sector is concerned, there is no government intervention.

Because of their informal character, yam-trading channels are generally not well understood or controlled. The amounts marketed cannot be inventoried and the official services in charge of monitoring the market do not know how the trading channels are organized or the types of transactions that occur. The actual prices used at the various stages of marketing can neither be effectively monitored nor controlled.

Because of the particular production and storage characteristics of yams, the main marketing difficulties involve harvesting and urban distribution. The marketing rhythm is always relatively slow; this leads to isolated transactions involving small quantities of yams. Marketing is carried out at the rhythm of the monetary needs of the household and the processing capacity of the family farm (chips). If there are no immediate needs, the family prefers to store the crop in the village for a few months and then sell it at the end of the season, when prices are more favourable. Since the crop consists of tubers, harvesting must be carried out on a regular basis. This

condition means that the person who does the collecting must make regular rounds in accordance with a schedule established by the producer. When access difficulties interfere with the regular rounds of the collectors, the producers sustain heavy losses because they have to sell at a loss; thus, they quickly lose interest in the market.

As far as the trading channels are concerned, three types can be distinguished. First, the direct channel, where the producer sells directly to the consumer in the local market, is the preferred method of supply in small towns. Second, the short channel involves only one middleman between production and distribution. In general, the middleman in a trader–collector who obtains the supply from the producer and resells the product at the end market. This type of channel is the most common and has the advantage of minimizing the number of operators, preventing the unchecked multiplication of profit margins, and facilitating regularity of harvest. Third, when supply lines are more than 200 km long and the flow is sufficiently large, the trading channel tends to multiply itself and form longer chains. In this case, the role played by the trader–collector is divided into two operations, that of the collector and that of the wholesaler.

Economic Impact

The production and marketing characteristics of yams pose a number of problems related to economics. The levels of production, which are generally static or dropping, and the lack of improved production materials lead to a situation in which production costs are continuously rising. In comparison to other crops, yams are usually grown a considerable distance from the trading centres. This leads to high distribution and marketing costs and low prices paid to the producer.

Social Problems

In the production areas, especially in the north, a significant proportion of yam production is used for local consumption. Women are generally responsible for marketing. For this reason, any program concerned with promoting the expansion of marketable crops must take into account the availability of women.

In most cases, yams are grown on a small scale at a subsistence level. Thus, the farm is both a production and a consumption unit and production schedules are generally closely related to the economics and organization of the household. Any effort toward maximizing production must take these facts into account.

The distibution of responsibilities in agricultural labour between men and women represents a singular obstacle to the expansion of yam cropping. To surmount this problem, it is necessary not only to have a thorough understanding of the social aspects of the rural economy, and particularly the decision processes involved, but also to develop policies for effective communication with the families of small farmers.

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ABSTRACTS

HARVEST INDEX OF FOOD YAMS AND ITS IMPLICATIONS FOR THE IMPROVEMENT OF TUBER YIELD

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Estimates of harvest index (HI) in food yams from published reports and field data indicate that improvements in tuber yield are more likely to result from cultural and genetic manipulations that proportionately reduce shoot size in relation to tuber output. At present, little is known about the dynamics of HI in yam production; consequently, more research is required to describe the functional relationships between plant parts with regard to photoassimilate partitioning. On a dry-weight basis, white yams are 6% root, 16% vine, 26% leaf, and 52% tuber; on a wet-weight basis, white yams are 9% root, 42% shoot, and 49% tuber. Variation in HI estimates strongly indicate that initial improvements in tuber yield are likely to be achieved by longer crop growth periods. The implications of adapting the HI concept to yam research and its possible effects on the design of efficient yam morphotypes are discussed. It appears that higher tuber yields will be associated with systems that maximize low inputs of sett, stake, soil nutrients, and water within a specified site and crop season.

TRADITIONAL YAM CROPPING IN THE SUDAN SAVANNA OF CAMEROON

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Intensive yam cropping is found in the Mbé area (600 m above sea level, 900–1200 mm annual rainfall) for commercial and home consumption. Specific varieties and cropping techniques used in this area are described. The high incidence of the "Dourou hut" mulching technique and its effect on the germination rate and production of the most commonly cropped varieties was examined. We evaluated production costs and time allocation between different cropping operations. Research into intensive cropping and the diversification of yam production in the Mbé area has been initiated.

INHIBITION OF SPROUTING BY GIBBERELLIC ACID (GA_3) IN THE PRESERVATION OF SEED AND WARE YAMS

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Gibberellic acid (GA_3) treatment delayed the sprouting of yam tubers by an average of 56 days in *Dioscorea rotundata* cv. Nwopoko and 75 days in *Dioscorea alata* cv. Um 680 compared with untreated tubers. In a few tubers of cv. Um 680, sprouting was completely suppressed for more than 9 months after harvest (MAH). GA_3 inhibited the sprouting of dormant as well as desprouted tubers. The duration of inhibition varied with GA_3 concentration, tuber size, and ambient temperature. Weight loss was reduced by 12–14% of the initial fresh

weight by GA_3 treatment. GA_3 reduced tuber dehydration more than it reduced dry matter loss. Tubers treated with GA_3 retained most of the qualities present at the start of the experiment (e.g., robustness and palatability) 9–10 MAH; however, the rate of growth of the yam vines was highly curtailed. When planted out as whole tubers, seed setts, or minisetts under irrigation in November (12 MAH), these planted materials showed normal sprouting and development.

Effect of Planting Depth and Orientation of Minisett Placement on Seed Yam Production

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The effects of four depths of planting yam minisetts (3, 6, 9, and 12 cm) and five placement positions (periderm up, periderm down, periderm to the side with head end up, periderm to the side with head end down, and periderm to the side with head–tail axis horizontal) on the growth and yield of seed yams were studied at Umudike in 1982 and 1983 using *Dioscorea rotundata* cv. Nwopoko. In 1984, five depths (3, 6, 9, 12, and 15 cm) were studied at one position. Four yam cultivars were used: Nwopoko and Abi (*D. rotundata*), Um 680 (*Dioscorea alata*), and Okumanu (*Dioscorea cayenensis*). All minisetts were planted on ridges at 40 000 plants/ha. The sprouting percentage at 9 weeks after planting showed no significant differences among depths or planting positions. The total tuber yield and percentage of tubers above 200 g were also not significantly affected by sett position or depth of planting. Cultivars differed significantly in sprouting and tuber yields. Six weeks after planting, the pest damage of sprouted setts was significantly higher at the 3 cm planting depth than at the other depths. The percentage of exposed and damaged tubers at harvest, however, was not statistically different for the various depths and positions. A planting depth of 9–12 cm was considered suitable for planting minisetts. This depth minimizes exposure by rainfall, pest damage, and sun-induced rot.

Effect of Tuber Portion on the Performance of Yams Grown from Minisetts

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The performance of *Dioscorea alata* cv. Um 680 minisetts obtained from head, middle, and tail regions of the tuber were compared in a field experiment at Umudike, Nigeria, in 1982. The trial was repeated in 1983 with six yam cultivars: Nwopoko, Obioturugo, Abii, and Ekpe (*Dioscorea rotundata*); Um 680 (*Dioscorea alata*); and Oko (*Dioscorea cayenensis*). There were no significant differences in total number, total yield, or yield of saleable tubers (> 200 g) among portions of tuber in both years. There were significant differences in yield between cultivars in 1983. No significant interaction between cultivar and tuber portion was observed. The results show that minisetts from any portion of the tuber can be used to establish a yam plantation.

Optimum Rate and Time of Fertilization for Yam–Maize–Cassava Intercrops

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Fertilizer trials were conducted at Umudike, Nigeria, to determine the optimum rate and time of fertilization in yam–maize–cassava intercrops. Five levels (0, 200, 400, 600, and 800 kg/ha) of compound fertilizer (15:15:15, N–P–K) were applied to the crop mixture at 3, 4, and 8 weeks after planting (WAP). Results showed that yields of maize grain, yam tuber, and cassava root increased significantly with increasing rates of fertilizer, reaching a maximum at 800 kg N–P–K/ha. Although fertilizer applied at 3 WAP gave the highest yields in all cases, the differences were not significant. Increases of over 15% in maize grain yield and over

45% in yam tuber and cassava root yields were obtained over sole cropping of maize, yam, and cassava at 400 kg N–P–K/ha. This rate gave a land equivalent ratio of 1.75, implying that about 75% of the land could be saved. For small-scale farmers in southeastern Nigeria, we recommend 800 kg N–P–K/ha at 3 WAP for yam–maize–cassava crop mixtures.

EFFECT OF DIFFERENT SEEDBEDS AND WEIGHTS OF SEED SETT ON THE HERITABILITIES OF TUBER YIELD PER PLANT AND THE YIELD COMPONENTS OF WHITE YAM (*DIOSCOREA ROTUNDATA*)

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In 1982, 1983, and 1984 at Port Harcourt, Nigeria, experiments were conducted on white yam (*Dioscorea rotundata* Poir.) to determine the effects of different seedbeds and weights of seed sett on the heritabilities of tuber yield per plant and its yield components. Five main observations were made. First, tuber yields per plant were significantly higher from mounds and ridges than from flats, holes, or trenches. Second, seed factor ratios were relatively higher for 100-, 200-, and 300-g seed setts than for 400-, 500-, and 600-g seed setts. Third, there were significant, positive correlations between fresh tuber yields per plant and number of tubers per plant, length of tuber, circumference of tuber, and weight of tuber; however, there were negative, nonsignificant associations among the other yield components. Fourth, heritabilities of tuber yield per plant and its components were comparable among seedbeds but decreased slightly as sett weight increased. Fifth, in selecting for higher tuber yields per plant, greater progress is likely to be made if selection is done on plants with fewer tubers per plant and raised from smaller seed setts.

Sweet Potato and Potato Breeding and Agronomy

SWEET POTATO AND THE AFRICAN FOOD CRISIS

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Sweet potato, among other root crops, plays an important dietary role in many parts of tropical Africa. It is grown over a wide range of environments mostly by small farmers. The importance of this crop as an efficient producer of biological material for human and animal food in intensive cropping systems is increasing. Its compatibility with various types of limited-input farming systems and its reliability under adverse conditions have made it an attractive crop to the farmer and the many national programs concerned with food self-sufficiency. To realize fully the benefits of the achieved research on this crop, national programs are encouraged to foreward results to the farmers in their effort to alleviate the African food crisis.

The urgent need to deal with the African food crisis has been emphasized this year by tactics that have sensitized the average person to the realities of mass starvation in Africa: i.e., "Band Aid," "Live Aid," "Sports Aid," etc. Indeed, greater awareness has stimulated many to offer assistance directly or indirectly. The International Society for Tropical Root Crops must address itself to declining food production, mass starvation, and its toll on human life.

Governments today are aware of the crisis and recognize the need to grow more food. In many parts of the continent, food self-sufficiency programs have gained priority, as evidenced by the implementation of revised agricultural policies and strategies. As population pressure increases and cultivations intensify, attention is focused on dry marginal areas, acidic valley bottoms, and on improving productivity with reduced inputs. One crop that lends itself to these conditions is the sweet potato.

BREEDING AND PRODUCTION POTENTIAL

Sweet potato has tremendous potential to be an efficient and economic source of food energy. Both roots and leaves are used and are good sources of provitamin A, vitamin B, vitamin C, calcium, iron, potassium, and sodium (Table 1). Besides this excellent nutritional quality, the sweet potato has a high yield potential in a relatively short growing season and an adaptability to a wide ecological range: 0–2300 m above sea level and 30°N to 30°S (Hahn 1984).

In densely populated, drought-prone areas, sweet potato also plays a vital role as a food security crop because of its resistance to drought. Despite these advantages, it is an important root crop in only a few countries in Africa: Rwanda, Burundi, and parts of Uganda, which are among the most densely populated regions of the continent. This implies that the role sweet potato has to play in relieving the hunger crisis in Africa has not yet been adequately exploited.

Over the last 15 years, plant breeders at the International Institute of Tropical Agriculture (IITA) have developed improved varieties of sweet potato with yield potentials of up to 40 t/ha in 4 months growth without fertilizers in well-managed soils. Resistance to major diseases and pests has also been identified (Hahn et al. 1983; Hahn 1984).

The successful application of tissue culture technology has made improved lines available to national programs with a minimum risk of spreading disease. Recipients evaluate and select improved lines for distribution or for crossing with local lines. Assessments by national programs of IITA source materials over many environments (Table 2) have lead to varietal releases by the national programs.

TOWARD FOOD SELF-RELIANCE WITH SWEET POTATO

Between 1960 and 1980, the local production of food fell sharply in sub-Saharan Africa. Per capita production fell by 7% during the 1960s and 25% during the 1970s, climaxing in the disastrous crop

[1] International Institute of Tropical Agriculture, Ibadan, Nigeria.

failures of 1983 and 1984 (UNICEF 1985). While this trend may apply to the general situations, however, countries with a strong root crop base did not suffer as much. In Rwanda and Uganda from 1970 to 1983, sweet potato production increased by 11 and 31%, respectively, to present outputs of 0.73 and 1.84 $\times$ 10^6 t, respectively.

During the last decade, there has been considerable progress in developing improved, high-yielding, early bulking sweet potato varieties, as well as technology to improve distribution. Nonetheless, serious deficiencies remain in terms of attention to the role that sweet potato should be playing in household food security and in sustaining a system of food entitlements.

The problems of drought, population shifts, and rapid population growth have worsened food shortages, malnutrition, and diseases, resulting in an alarmingly high loss of human life. Realizing that carbohydrates are the most important source of food energy, making up more than 40% of total caloric needs, there is an urgent need to place more emphasis on sweet potato as an efficient and reliable source of food energy.

Means for Increasing Productivity

The increase in efficiency and productivity required to alleviate the current food crisis will not be achieved simply by introducing new varieties. The potential for expanding the cultivated land is limiting. Ecosystems in marginally productive areas are already strained and fragile and can barely be more intensively cultivated. In essence, solutions are few; however, the intensive production system of some of the most densely populated countries in Africa, such as Burundi and Rwanda, are providing us with useful and encouraging models. The contribution from these countries is uniquely important. The current best-known production practice provides us with some of the greatest opportunities.

There are three main characteristics to this model. First, productivity is increasing as cropping systems become more intensive and less extensive in terms of resource inputs, land use, and management. In Rwanda, it is said that only those who have nothing to do weed sweet potato fields. This type of intensive crop management leaves nothing to chance, more fully exploits the genetic yield potential, and can significantly reduce fertilizing, pest control, weeding, and other resource inputs.

Second, the success of sweet potato in Rwanda is built upon the versatility of this crop in its ability to synchronize its growth cycle and adapt to local climatic changes and soil factors. For example, up to three crops can be grown each year (one in the valley and two on the hill slopes). The most common cause of crop failure in new environments is a lack of synchrony of the crop growth period with the sequence of seasonal conditions. The other factor contributing to the success of sweet potato in Rwanda is its high compatibility with the low-input, intensive farming system that directly affects small, subsistence farmers. Thus, farmers unable to hire labour during the peak season know that sweet potato can wait. As such, it does not compete for planting and harvest labour. Farmers can propagate their own planting stock and the sweet potato can always be a source of year-round income. The mean area of a sweet potato farm in Rwanda is about 0.05 ha.

Third, the intensive utilization of sweet potato as a home garden plant and as a field crop has contributed significantly in meeting nutritional and year-round food security needs in Rwanda. The government of Rwanda recognizes the vital role of sweet potato as a food bank; farmers are encouraged always to have a plot of stagger-planted root crops (sweet potato and cassava) in their fields and home gardens. The use of this intensive sweet potato production system should be further examined and adapted and improved where possible.

Table 1. Nutrient content of sweet potato.

Nutrient	Quantity
Carbohydrate (% dry matter)	91.0
Protein (% dry matter)	4.3
Energy (J)/100 g	477.3
Calcium (mg)	32
Phosphorous (mg)	47
Iron (mg)	0.7
Sodium (mg)	10
Potassium (mg)	243
Magnesium (mg)	31
Vitamin A (IU)[a]	8800
Thiamine (mg)	0.10
Riboflavin (mg)	0.06
Niacin (mg)	0.06
Vitamin C (mg)	21

Source: Salunkhe (1976).
[a]IU, international units.

Table 2. Mean yields (t/ha) of improved and local populations of sweet potato in four national programs.

Nation	Improved population	Local population
Rwanda	23 (10–39)[a]	10 (7–13)
Malawi	23 (5–42)	7 (0.4–19)
Mozambique	21 (11–30)	9 (0.5–17)
Tanzania	22 (18–26)	15 (8–22)

[a]Ranges are shown in parentheses.

CHALLENGES

The present food crisis requires immediate action. Unfortunately, there are few, if any, shortcuts for increasing crop productivity and sweet potato is no exception. Some of the constraints that should be considered as priority areas are biological stress, environmental stress, postharvest quality, and limited food forms.

BIOLOGICAL STRESS

DISEASES

Sweet potato virus disease is caused by a two-component virus complex (flexuous filamentous rods). The two components are each transmitted by a different vector, one by the whitefly (*Bemisia tabaci*) and the other by aphids (*Aphis gossypii, Aphis citricola*). The typical symptoms include vine-clearing chlorosis, puckering, leaf strapping, leaf curling, and stunting. This disease is widespread in Africa with varying effects on yield, which can be reduced by up to 80% (Hahn et al. 1983; Theberge 1985).

Altanariose is caused by the pathogen *Altanaria* sp. The first symptoms appear as small brown to black flecks on the foliage, petiole and stem. Under favourable conditions for growth and development of the fungus, the plant will loose its leaves resulting in a total collapse of the vines.

PESTS

Sweet potato weevil (*Cylas puncticollis* and *Cylas formicarius*) is the most widespread and damaging insect pest of sweet potato, causing crop losses of 12–90%. The adult weevils attack leaves and vines, but the most serious damage is caused when adults and larvae tunnel through the tubers resulting in subsequent rot because of bacteria and fungi.

The sweet potato butterfly (*Acraea acerata*) is an occasional pest that comes during the dry season, with devastating effects. The caterpillars feed on the leaves, leaving only skeletons of primary midribs intact. A heavy attack often results in complete defoliation.

Root-knot nematodes (*Meloidogyne incognita, M. javanica, M. arenaria*, and *M. hapla*) are pests that attack the feeder roots and storage roots. This can result in deformation and rotting and reduce yields by 20–30%.

ENVIRONMENTAL STRESS

Although sweet potatoes will grow in acidic soils, yields decrease by up to 60%. Similarly, in the higher altitude areas of the tropics, where temperatures are cooler, growth cycles are increased and yields are reduced. Yields are also reduced when sweet potatoes are grown in poorly drained hydromorphic soils.

POSTHARVEST QUALITY

Sweet potatoes do not store for very long after harvest in ambient conditions. If weevils are present, postharvest quality is reduced very rapidly.

LIMITED FOOD FORMS

Sweet potatoes are usually boiled or baked for human consumption. Other forms of preparation for consumption are not popular, but should be explored.

PRIORITIES FOR ACTION

Long-term measures are required to overcome the constraints to sweet potato productivity. Furthermore, there is no doubt that the current African food crisis demonstrates the need to pursue policies that encourage greater national self-reliance and food security.

The first requirement for ensuring the greater use of root crops in promoting food security is to encourage the establishment of National Root Crops Programs (NRCPs). It is usually these NRCPs that have the first-hand information and experience on the problems and usually seek practical solutions to them.

It has been more than a decade since IITA focused its research on sweet potato. The impact of this research would be evident in more African countries if the NRCP capacity existed to adapt such research results to local conditions. These NRCPs must also consider themselves as integral components of the total research system, setting the forces and trends for the progress of sweet potato. Although great gains have been made in breeding sweet potato for disease and pest resistance and for yield in general, there is still a great genetic potential that has yet to be exploited for adaptation to yield-limiting biological and environmental stresses.

Tropical root crops in general are not easily stored on a large scale after harvest. Further gains can be made in prolonging the shelf life and ensuring good consumer quality, and there is a need to diversify the preparation of sweet potato to improve consumption. The identification of nonsweet types will potentially modify taste hinderances to sweet potato consumption and increase flexibility in preparation.

The sweet potato is an important tool for training. It provides opportunities for students to do short-term projects. Other areas that warrant continued attention are nitrogen fixation by sweet potato root–

microbe associations and areas of specific relevance and priority in some national programs. Research and development results on sweet potato must be used as input for the formulation of policies; otherwise, policies err in design and execution.

Finally, as national programs evolve, there will be a need to strengthen interprogram ties in the form of networks. Such a covenant will enable regional programs to exploit effectively the limited personnel and physical resources available and will encourage us to face the future with an organized strength and to sustain a productive process necessary for tackling the African food crisis.

The growing food needs of Africa will continue to be served by the small, limited-input farmer. The needs of these farmers should continue to be our priority. Small farmers can be some of the most efficient producers in Africa, but one of the key ingredients necessary for them to attain their efficiency and effectiveness is the application of the science-based information and technology now available. This is particularly true for sweet potato and other root crops.

Conclusions

Severe food shortages in Africa have led to considerable suffering and provoke concern for the years ahead. Considering the potential of sweet potato, national programs cannot afford to neglect its development. For Africa to meet the challenge of sustaining productivity, we must continue to communicate the problems and potentials of root crops and persuade policymakers and politicians to strengthen their support for root crop development.

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EFFECT OF MULCH ON DRY-SEASON YIELDS OF 10 POTATO VARIETIES IN THE JOS PLATEAU OF NIGERIA

O.P. IFENKWE AND D.D. TONG[1]

Two trials during the dry seasons of 1984 and 1985 examined the effects of mulch on the yield of 10 potato varieties. The mulching material was dry *Andropogon* spp. grass. In each growth period, the crops were irrigated at a rate equivalent to 19.5 mm rainfall every 2.5 h twice weekly in 1984 and three times weekly in 1985. All varieties were harvested when the last maturing variety was ready. Weeds were chemically controlled. In the 1985 crop, herbicide toxicity affected line RC767-2. During this season, bacterial wilt (*Pseudomonas solanacearum*) affected cv. Arka, especially in the mulched plots. Soil temperatures were recorded at 5-, 20-, and 30-cm depths in both mulched and unmulched plots at 1000 and 1400 daily. In both dry seasons, mulching increased yields. In 1984, the overall yield was increased by 41.7%; in 1985, the yield of 9 out of 10 varieties increased by 11.7%. Mulching reduced soil temperature considerably, especially in the upper 5 cm after midday. Differences in temperature between mulched and unmulched treatments decreased with increasing soil depth. There was less temperature fluctuation in the mulched treatment. Higher yields in the mulched treatment were attributable to better moisture retention and lower soil temperatures.

Greater production of potato in Nigeria in the dry season is constrained by inadequate soil water during crop growth. Even when water is available, it is necessary to conserve it until crops mature in the field. The cost of irrigating the potato crop is prohibitive; therefore, any practice that favours the efficient use of water is welcome.

Mulching benefits potatoes grown during dry weather (Midmore 1983) because of reduced soil temperatures (CIP 1983). In Vietnam, inadequate soil moisture decreased the yield of potato, but the use of mulch conserved soil moisture (CIP 1984). In Bangladesh, the use of mulch enabled planting 1 month before the optimum planting date (CIP 1984). Mulching and early sprouting of sett tubers can be employed in northern Nigeria to achieve more flexible planting dates and longer harvest periods, thus helping to maintain price levels for farmers (CIP 1984).

In Nigeria, mulching significantly improved tomato fruit yield; the effect of mulch was also shown to be more marked in the drier season (Adelana 1979). Adelana (1979) also noted mulched plots had less weeds. Mulching suppressed large-leaved weeds in all plots and reduced the weeding cost by over 50%.

The present study investigated the effect of mulch on dry-season potato yield, with a view to avoiding irrigation.

MATERIALS AND METHODS

Two trials were conducted in the dry seasons of 1984 and 1985 to investigate the effect of mulch on the yield and growth of 10 potato varieties. In each year, a 2 × 10 factorial combination of mulched and unmulched treatments with 10 potato varieties were tested using a randomized complete block design with four replications. The mulch material was dry *Andropogon* spp. grass. The gross plot size was 24 m^2 and the sett plot was 12 m^2.

The experiments were planted on 10 October 1984 and 15 November 1985 and harvested on 8 January 1985 and 4 March 1986, respectively. Water was supplied by overhead irrigation at a rate equivalent to 19.5 mm rainfall for 2.5 h twice weekly in the 1984 season and three times weekly in the 1985 season. Weeds were chemically controlled with Metribuzin (pre-emergent) at 0.7 kg active ingredient/ha before mulching. Soil temperatures were recorded at 5-, 20-, and 30-cm depths in both mulched and unmulched plots at 1000 and 1400 daily. At harvest, total tuber yields were recorded for all plots.

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Table 1. The effect of mulch on the total tuber yield (t/ha) of 10 varieties of potato

Variety	Mulched[a]		Unmulched[a]		% change		Mean[b]	
	1984	1985	1984	1985	1984	1985	1984	1985
RC767-2	27.8	20.4	14.2	17.1	95.8	19.2	21.0	18.8
B9462-1	17.7	32.9	12.4	31.7	42.7	3.6	15.1	32.3
Greta	17.3	26.9	13.3	21.3	30.1	26.5	15.3	24.1
Arka	17.4	31.5	11.9	36.8	31.6	−17.0	14.7	34.2
Nicola	17.2	22.3	12.3	19.6	39.8	14.0	14.8	21.0
Spunta	17.3	30.7	11.4	25.0	34.1	22.5	14.4	27.9
Mirka	23.7	35.8	17.4	30.6	36.2	17.3	20.5	33.2
Desiree	15.7	23.3	12.4	20.7	26.6	12.8	14.1	22.0
RC777-3	20.2	28.2	15.5	26.7	30.3	5.5	14.9	27.5
B9493-4	18.7	26.1	12.5	23.2	49.6	12.7	15.6	24.6
Mean	19.3	27.8	13.4	25.3	41.7	11.7	—	—

[a] LSD ($P = 0.05$) between mulched and unmulched treatments: 1984, 1.23; 1985, 2.93.
[b] LSD ($P = 0.05$) between varieties (mean values): 1984, 2.81; 1985, 6.46.

Results

Total Tuber Yields

In 1985, the higher irrigation frequency appeared to benefit unmulched plots such that tuber yields were generally much higher for both mulched and unmulched plots in 1985 than in 1984. There were two exceptions: line RC767-2, which showed symptoms of Metribuzin toxicity, and unmulched plots of cv. Arka, which yielded more than the mulched plots because of the high incidence of bacterial wilt (*Pseudomonas solanacearum*) in the mulched plots, which reduced stand count. Nevertheless, mulching increased total tuber yield in all other varieties, although the magnitude of the increase was not as marked in 1985 as in 1984 (Table 1).

In 1984, dry-season mulching increased tuber yields in all varieties: from 26.6% in Desiree to 95.8% in RC767-2 (Table 1). Late-maturing varieties, such as RC767-2 and B9462-1, and medium-maturing varieties, such as Greta and B9493-4, benefited most from mulching.

Soil Temperature

In 1985, the soil temperatures were reduced by mulching, although to a lesser extent at every depth than in 1984. This was apparently due to the more frequent irrigation in 1985. Soil temperatures fluctuated as in 1984 (Fig. 1).

In 1984, mulching reduced soil temperatures considerably, especially in the upper 5 cm. Differences between unmulched and mulched treatments were greater at 1400 than at 1000 (Figs. 2a and 2b). The difference between mulched and unmulched treatments decreased as soil depth increased (Figs. 2c, 2d, 2e, and 2f).

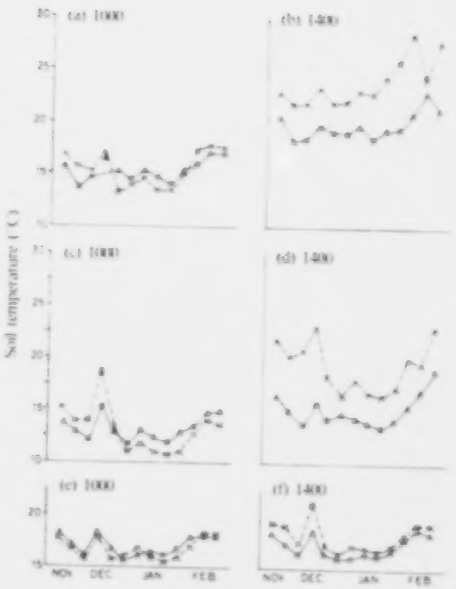

Fig. 1. *The effect of mulch (△, mulch; ×, unmulched) on mean weekly soil temperatures in 1985 at 1000 and 1400 at (a,b) 5-cm, (c,d) 20-cm, and (e,f) 30-cm depths.*

Discussion and Conclusion

In Peru, Midmore (1983) showed that maximum day temperature at tuber-planting depth (5–7 cm) was 5–7°C lower in the mulched than in the unmulched treatment; however, at night, the minimum temperature was 2°C higher in the mulched than in the unmulched treatment. This temperature pattern

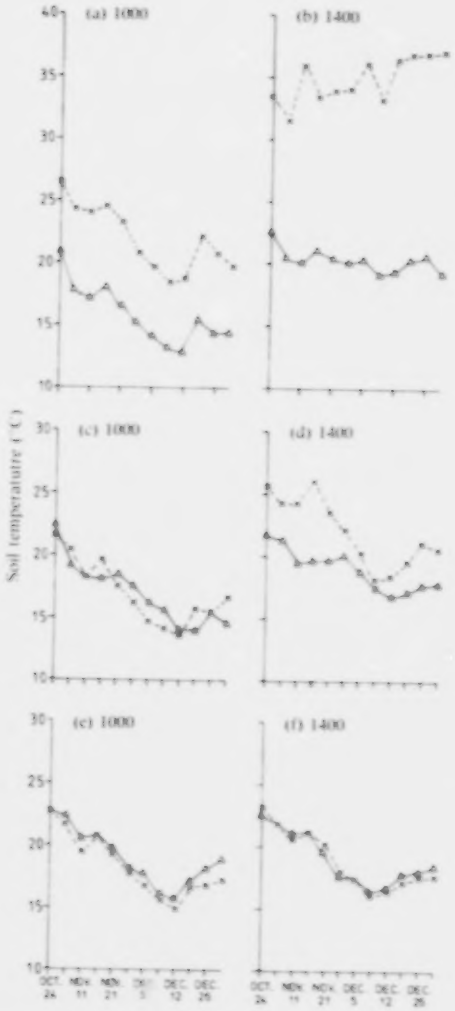

Fig. 2. *The effect of mulch (□, mulched; ×, unmulched) on mean weekly soil temperatures in 1984 at 1000 and 1400 at (a,b) 5-cm, (c,d) 20-cm, and (e,f) 30-cm depths.*

agrees with the results of this study, that mulched plants are less affected by temperature fluctuations. It also appears that the optimum benefit of mulching occurs where water is scarce. In such cases, mulching reduces the frequency of irrigation, lowers the soil temperature, and favours tuber bulking in potato. Mulch forms a physical barrier between the soil and the air and reduces soil moisture less in exposed soils. This is important under conditions of high evapotranspiration, which is a common feature of the dry harmattan months in northern Nigeria. The problem of bacterial wilt, which occurred in mulched plots during 1985, may have been due to the planting of infected seed tubers, since bacterial wilt was not usually associated with mulching (Ifenkwe et al. 1985).

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EFFECT OF PLANT DENSITY ON SWEET POTATO YIELDS IN CAMEROON

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Sweet potato (*Ipomea batatas*) breeding and selection by the Cameroon National Root Crops Improvement Programme to reduce constraints to sweet potato production led to the release of clones that tolerate pests and diseases and give higher yields than local cultivars. The standard planting of sweet potato is 3 plants m^2 on ridges. Three improved clones of sweet potato (TIb 1, TIS 2498, and 1112) were tested at three population densities: 10 000, 20 000, and 30 000 plants/ha. Plant vigour was excellent at 20 000 and 30 000 plants/ha and the number of weeds decreased with increasing plant population. The number of tubers increased with increasing plant population, whereas tuber size decreased. Each clone showed its highest total tuber yield and percentage of marketable yield at 20 000 plants/ha. This population density appears to be more suitable than the standard 33 000 plants/ha when tuber yield and production of planting material are considered.

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a dicotyledonous plant native to Central America. Its growth cycle varies from 3 to 7 months depending on cultivar and environment. Sweet potato is mostly grown for the edible tubers but also for the leaves, which are a good source of minerals and vitamins (Kay 1983). In parts of Cameroon, the leaves are eaten as vegetables or fed to livestock. Sweet potato is grown over a wide range of environments between 40° N and 40° S, and from sea level to 2300 m altitude (Hahn and Hozyo 1984). Although sweet potato grows in areas of relatively high rainfall, it does not withstand waterlogging and is usually grown on mounds or ridges.

Because Cameroon has diverse agroecologies, the Cameroon National Root Crops Improvement Programme (CNRCIP) has partitioned the country into five zones based on climate, phytogeography, and altitude. Sweet potato is grown in all five of these zones. The local cultivars are mostly grown, but production is contrained as a result of poor cultural techniques, diseases, and a lack of improved varieties. The cropping patterns vary with the culture.

Sweet potato is sometimes intercropped with maize, cassava, beans, or vegetables. Seed beds are usually ridges or mounds 30–50 cm high. In rain-fed areas, sweet potato is grown for two seasons in Cameroon. Sweet potato used to be regarded solely as a livestock feed or as a food for children. Recently, however, the awareness of its nutritive value and the availability of improved clones has led to an increase in demand and production (Cameroon Ministry of Planning and Regional Development 1981).

Advances in the selection of improved sweet potato clones adapted to the various zones in Cameroon require the development of improved cultural techniques. It is normal practice to plant three sweet potato vine cuttings per square metre. On-farm research trials in Cameroon tended to question this population density as being the most appropriate (CNRCIP 1984). It was on this basis that density studies were carried out on elite sweet potato clones selected at agroecological zone II in Cameroon to determine an optimum plant density.

MATERIALS AND METHODS

The experiment was conducted in 1984 and 1985 on medium-young volcanic soils in Cameroon. Three elite clones of sweet potato (TIb 1, TIS 2498, and 1112) were tested at three population densities: 10 000, 20 000, and 30 000 plants/ha. Beds were 6 m long and 1 m apart. The design was randomized complete block with four replicates. Vine cuttings (30 m long) were planted in the first (March) and second (August) seasons and harvested 4 months after planting. Observations were made on plant vigour, incidence and severity of weeds, and final evaluation of tuber yields at harvest.

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Table 1. Effect of population density on yield of sweet potato clones.

Clone	Stand count/10 m²				No. of tubers/10 m²				Tuber yield/10 m²			
	10[a]	20	30	Mean	10	20	30	Mean	10	20	30	Mean
First season												
TIb 1	8	14	19	14	47	73	103	74	20.4(56)[b]	23.8(53)	24.1(55)	22.7(56)
1112	10	19	26	18	76	118	134	109	32.1(55)	37.4(54)	33.7(55)	34.4(54)
TIS 2498	8	19	27	18	32	71	109	71	14.4(51)	27.6(52)	25.9(54)	22.6(52)
Mean	9	17	24		52	87	115		22.3(54)	29.6(53)	27.9(55)	
Second season												
TIb 1	10	13	18	14	57	100	123	93	11.3(85)	19.7(77)	15.0(75)	15.3(79)
1112	10	13	19	14	62	89	145	99	15.6(86)	19.5(78)	16.9(60)	17.3(75)
TIS 2498	10	13	19	14	58	80	98	79	13.1(89)	16.9(74)	18.5(80)	16.1(81)
Mean	10	13	19		59	90	112		13.3(87)	18.7(76)	16.8(72)	

Note: All values were measured at harvest.
[a]Population density ($\times 10^3$ plants/ha).
[b]Values in parentheses represent the percentage marketable yield.

Table 2. Weed intensity at three sweet potato population densities.

Population density ($\times 10^3$ plants/ha)	Weed intensity score[a] (per 10 m²)					
	First season			Second season		
	TIb 1	1112	TIS 2498	TIb 1	1112	TIS 2498
10	2.3	1.0	3.0	2.0	1.0	2.0
20	1.3	0.8	2.3	1.1	0.5	1.7
30	1.5	0.3	2.0	0.9	0.3	1.1
Mean	1.7	0.7	2.4	1.3	0.6	1.6

[a]0, no weeds; 1, light weeds; 2, moderate weeds; 3, heavy weeds.

Results and Discussion

An increase in the number of stands per plot was associated with an increase in the number of tubers. Mean tuber yields were highest at 20 000 plants/ha (Table 1).

The incidence and severity of weeds was greatest at 10 000 plants/ha for each clone (Table 2). There were also more weeds in the first season than in the second season (Table 2). The establishment of vines increased from clones 1112 to TIb 1 to TIS 2498 in both planting seasons. The establishment of plants increased from 10 000 to 30 000 plants/ha for each clone.

Ndamage (1984) reported higher sweet potato tuber yields at a planting distance of 50 cm on ridges than at 80 cm. Lyonga and Ayuk-Takem (1984) obtained high tuber yields with 20 000 plants/ha and reported that two weedings before harvest was adequate. The 10 000 plants/ha treatment received three weedings before harvest because of slow plant-canopy establishment, with attendant weed growth. The 20 000 and 30 000 plants/ha densities received one weeding and a subsequent spot removal of weeds and were, therefore, cheaper to maintain than the 10 000 plants/ha density.

The gradual elimination of constraints to sweet potato production by selecting elite clones that are tolerant to diseases and pests points toward increased production. The 20 000 plants/ha density appears suitable for optimizing tuber yield. More planting material will be conserved than with the 30 000 plants/ha density and it would be cheaper to maintain than the 10 000 plants/ha density. The 20 000 plants/ha population will also fit well in the cropping system of peasant farmers (usually mixed intercropping) and, as such, will be recommended for the creeping varieties of sweet potato.

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SELECTING NONSWEET CLONES OF SWEET POTATO FROM THE IITA GERM PLASM COLLECTION

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Sweetness is an undesirable quality in a staple food. The potential of sweet potato as a staple food, therefore, depends on developing nonsweet lines. To accomplish this objective, the International Institute of Tropical Agriculture (IITA) sweet potato germ plasm collection was screened for nonsweet clones. Total soluble and reducing sugars in the flour of both raw and baked tubers were determined. Relative amylase activity was also determined in polyacrylamide gel with soluble starch as the substrate and iodine as the stain. Although the method based on relative amylase activity is rapid and simple, the observed activity was not correlated with increases in sugar content or total sugar concentration after baking. Therefore, further modifications in this screening procedure are required. Since sweetness is dependent on more than just reducing sugar concentration, total sugar concentration was used to select the nonsweet clones. A total soluble sugar content in the baked tuber flour greater than 20% on a dry weight basis was considered sweet. Among the 380 clones screened, 60 were classified as nonsweet.

Cooking increases the sweetness of sweet potato roots as a result of starch breakdown by amylases into sugars and dextrins at the initial stage of the preparation (Palmer 1982). Because sweetness is an undesirable quality in a staple food, the potential of sweet potato as a staple food, therefore, depends on the development of nonsweet lines.

A sweet potato cultivar in which the starch is not converted to sugar by cooking was first reported by Martin and Ruberte (1983). Since this finding, more nonsweet and less-sweet clones have been found; they are now called staple-type sweet potatoes (Martin 1986). The objective of this study was to identify such staple-type sweet potatoes in the International Institute of Tropical Agriculture (IITA) sweet potato germ plasm collection of 570 clones.

MATERIALS AND METHODS

PREPARATION OF FLOUR

To obtain flour from raw tuberous roots of sweet potato, the roots were peeled, sliced into thin chips, oven-dried at 55°C, and milled. Flour from baked roots was prepared by cutting the raw roots into halves or quarters, depending on their size, wrapping the pieces in aluminum foil, baking them at 225°C for 1 h, peeling and mashing the baked root, and oven-drying at 55°C before milling.

SUGAR ANALYSES

The total soluble sugar content was determined using the phenol sulfuric acid method (Dubois et al. 1956). Sugars were extracted from the flour with 80% ethanol and then reacted with phenol and sulfuric acid, producing an orange chromophore. The ethanol extract was also analyzed for reducing sugars using the Folin and Wu micromethod (Horwitz 1970). Reducing sugars were reacted with $CuSO_4$ and phosphomolybdic acid, forming a blue solution.

AMYLASE ASSAY

The procedure of Martin (1986) was modified to measure relative amylase activity in the raw tuberous root. Cubes of raw root (0.5 cm^3) were macerated in 0.8% NaCl – acetate buffer (0.2 *M*, pH 5.5; 1 g mL^{-1}). Filter-paper strips saturated with the extract were inserted into slits in 5% polyacrylamide gel in small petri dishes for 30 min. The gel was covered with 0.5% soluble starch in 0.2 *M* acetate buffer for 1 h and then rinsed with distilled water. The petri dish was covered, steamed in a water bath for 15 min, and allowed to cool to room temperature. The gel was covered with 0.1% I$_2$ in 1% KI and 0.2 *M* acetate buffer for 30 min. Relative amylase activity was scored on a scale from 1 to 3 based on the size of the lighter blue or colourless spot: 1, no detectable activity; 2, low or medium activity; 3, high activity.

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RESULTS AND DISCUSSION

Among the 570 clones in the IITA sweet potato germ plasm collection, 380 clones were analyzed. Increased sugar concentrations were observed after baking (Fig. 1) because of the conversion of starch to sugars and dextrin by the α- and β-amylases present in sweet potato (Palmer 1982).

Increases in total soluble sugars and in the reducing sugar concentration after baking varied among clones. The amount of reducing sugars produced was not equal to the additional total soluble sugars detected for the clones (Table 1). The sugar concentrations in TIS 8027 and TIS 8267 did not change after baking, indicating the absence of amylase activity in these clones. Increases in total soluble sugars in TIS 8504, TIS 84-0007, and TIS 84-0026 were not associated with changes in the reducing sugar concentration, suggesting that amylase activity varies among clones. There are many possible sources of variation, e.g., differences in enzyme concentration, presence (or absence) of inhibitor, varying degrees of branching in starch, etc. (Martin and Deshpande 1985, Walter et al. 1975).

A preliminary taste panel evaluation (n = 15) of baked and boiled sweet potatoes was conducted for clones TIS 8504, TIb 4, TIS 2498, and TIS 8250, having baked tuber total soluble sugar concentrations of 18.6, 48.8, 26.8, and 24.8%, respectively. Tasters were asked to rate each clone as sweet, moderately sweet, or not sweet. TIS 8504 was never rated sweet (IITA 1986). Sweetness of the cooked sweet potato depends on the content of total soluble sugar rather than reducing sugar alone. Based on the sweetness rating and total soluble sugar concentration of TIS 8504, a total soluble sugar concentration in the baked tuber flour of 20.0% or less on a dry-weight basis was regarded as nonsweet. Among the 380 clones screened, 60 were classified as nonsweet.

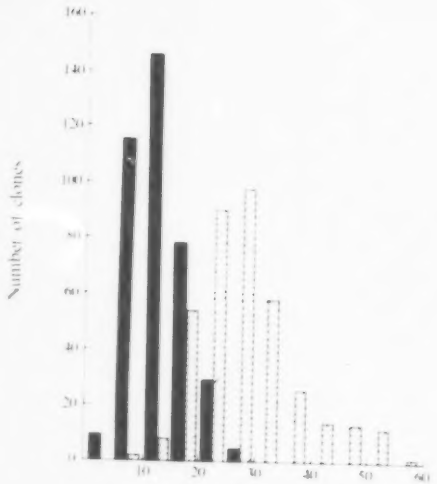

Fig. 1. *Total soluble sugar concentrations in raw (■) and baked (▨) tuber flour (dry-weight basis).*

A high amylase activity is associated with a greater conversion of starch into sugar during the baking of sweet potato. Analyses of variance using the data for 380 clones showed that relative amylase activity affects the total soluble sugar concentration in baked tuber (P = 0.001) and the increase in total soluble sugar concentration (P = 0.01).

Table 1. Changes in sugar concentrations in the dry flour of some nonsweet clones of sweet potato.

Clone	Relative amylase activity[a]	Total soluble sugar (baked tuber)(%)	Increase in total soluble sugar (%)[b]	Increase in reducing sugar (%)[c]
TIS 8027	2	9.68	−0.73	−0.09
TIS 8267	2	8.41	0.04	−0.45
TIS 9191	3	19.55	−0.32	2.43
TIS 8504	3	18.57	4.00	0.46
TIS 84-0007	3	20.20	2.56	0.60
TIS 84-0026	3	19.81	2.14	1.13
TIS 2154	3	14.57	8.22	12.08
TIS 2347	2	12.71	5.97	4.30
TIS 3059	3	15.84	10.34	1.36
TIS 2153	3	19.99	13.40	0.20
TIS 3161	3	17.77	11.74	3.43
TIS 3180	2	17.49	14.39	3.24

[a] 1, no detectable activity; 2, low or medium activity; 3, high activity.
[b] Increase in total soluble sugar = total soluble sugar in baked tuber − total soluble in raw tuber.
[c] Increase in reducing sugars = reducing sugar in baked tuber − reducing sugar in raw tuber.

The procedure for determining relative amylase activity was simpler and faster than analyzing total soluble sugars in baked tuber flour. However, relative amylase activity is a poor indicator of total soluble sugar concentration (Table 1) and the technique requires modifications to be effective in screening for nonsweet lines of sweet potato.

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ABSTRACTS

EFFECT OF SEED POTATO STORAGE DURATION ON SUBSEQUENT FIELD PERFORMANCE OF *SOLANUM TUBEROSUM* CULTIVARS IN THE JOS PLATEAU OF NIGERIA

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The conventional method for long-term seed potato storage is cold storage. Because cold storage is expensive to install and maintain, most potato farmers in the Jos Plateau of Nigeria store seed at room temperature. This study compared the field performance of three cultivars (Nicola, Greta, and B6934-11) of seed potato (*Solanum tuberosum* L.) stored for 3 months at room temperature (24°C) with that of seed stored for 7 months at 4°C. Tuber weight, sprout length, and number of sprouts were determined after storage. The results showed that seed stored for 7 months at 4°C lost more weight and had more sprouts than seed stored for 3 months at 24°C. Sprout lengths under both storage conditions were not significantly different. Seed potato stored for 3 months at 24°C yielded higher total and large-size tubers, but fewer small-size tubers than did seed potato stored for 7 months at 4°C. Total number of tubers was not significantly affected by the duration of seed storage.

EFFECT OF POTATO CULTIVAR MATURITY RATES AND PLANT DENSITIES ON GRAIN AND TUBER YIELDS OF MAIZE–POTATO INTERCROPS IN THE JOS PLATEAU OF NIGERIA

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Experiments were conducted in 1985 at Kuru near Jos, Nigeria, to determine the effects of potato cultivar maturity rates and plant densities on grain and tuber yields of maize–potato intercrops. Two potato cultivars, B9462-1 (early maturing) and RC777-3 (late maturing), each at three densities (16 667, 25 000, and 33 333 plants/ha), were intercropped with maize (cv. Farz-7) at the same three densities. The late-maturing potato cultivar (RC777-3) reduced grain yield by 21% but increased tuber yield by 11% over cv. B9462-1. Increasing the maize density from 16 667 to 33 333 plants/ha reduced potato yield by 29%; however, a similar increase in the potato density did not significantly reduce grain yield. Potato and maize yields significantly increased with increases in potato and maize densities, respectively.

VARIABILITY OF SOME FOOD NUTRIENTS IN CULTIVARS OF SWEET POTATO

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Fresh sweet potato tubers of various cultivars harvested 18 weeks after planting showed starch and reducing sugar contents of 17.2–22.5% and 0.6–1.8%, respectively. The application of fertilizer to various sweet potato cultivars affected the dry matter, crude fibre, crude protein, and ash contents of the leaves. In cv. Dokobo, the only response to fertilizer application was a 6% increase in crude protein. Cultivars also varied in some leaf nutrients. Nutrient variability in sweet potato tubers and leaves is likely due to variations in soil fertility.

EFFECT OF LIME AND N–P–K FERTILIZATION ON SWEET POTATO IN EARLY AND LATE SEASONS AT PORT HARCOURT, NIGERIA

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An experiment was conducted at Port Harcourt, a humid, high-rainfall zone of Nigeria, to determine the effects of liming (0, 2, and 4 t ha) and N–P–K fertilization (15:15:15 at 0, 200, 400, and 600 kg ha) on sweet potato (TIb 11) grown in early (March–August) and late (September–December) seasons on a typic paleudult soil with pH of 5.1, 0.012% N, 31 ppm available P (Bray's P_1), and 0.12, 1.79, and 0.31 mequiv. 100 g soil of K, Ca, and Mg, respectively. Fertilization increased vegetative growth by increasing branching, dry weights of leaves and stems, and leaf area. Liming tended to decrease stem dry weight without significantly affecting leaf weight or branching. Storage root yield (7.3–11.0 t ha) was increased by N–P–K at 200 kg ha. Beyond that rate, fertilization decreased yield by reducing the number of storage roots per plant and increasing the percentage of storage roots bigger than 150 g. Liming, which increased pH to 5.7, decreased the yields by reducing the number of storage roots per plant without a compensatory increase in root size. In the late season, storage roots matured within 3 months with about 62% of them at stem base and the rest at nodes of creeping vines. In the early season, the roots matured after 4 months with only 8.6% of the storage roots at the stem base.

MOST PROBABLE NUMBERS OF NITROGEN-FIXING BACTERIA ASSOCIATED WITH SWEET POTATO ROOTS

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Fibrous and storage roots of four varieties of sweet potato were evaluated for rhizosphere populations of *Azospirillum*. Most probable numbers (MPNs) of *Azospirillum* ranged from 0.02×10^6 to 5.4×10^6 cells/g dry root, depending on the variety and field sampled. MPN of *Azospirillum* associated with TIS 9265 was consistently higher than MPNs associated with the other clones evaluated.

GROWTH RESPONSE OF SWEET POTATO TO PHOSPHORUS AND MYCORRHIZAL INFECTION

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Mycorrhizal infection of 10 sweet potato cultivars was assessed in potted soils from Fashola, Ibadan, and Onne, Nigeria. Pots were arranged in a randomized complete block design with four replicates. All cultivars showed mycorrhizal infection by indigenous fungi 7 weeks after planting (WAP): Fashola soil, 24%; Ibadan soil, 17%; Onne soil, 7.4%. Plants grown in Fashola soil had similar phosphorus (P) contents as plants grown

in Onne soil; sweet potato grown in the Ibadan soil had the lowest P content. Shoot dry weights, however, were 50% higher in Ibadan soil than in the Onne and Fashola soils. Mycorrhizal infection of sweet potato differed among varieties and with soil origin. Sweet potato inoculated with mycorrhized roots of *Leucaena leucocephala* in partially sterilized Ibadan soil showed an average mycorrhizal infection of 23.1%; uninoculated plants had a 4.1% infection rate. In both treatments, however, dry matter production at 9 WAP was similar. When TIb 4 (a local variety) and TIS 9265 (an improved variety) were grown in the presence of 50 to 100 ppm P from single superphosphate, TIb 4 produced 37% more dry matter at 9 WAP; however, its mycorrhizal infection was reduced when 100 ppm P was applied. The growth of TIS 9265 was not affected by P fertilization. Cultivars like TIb 4 that respond to P fertilization are likely to benefit from mycorrhizal infections in P-deficient soils.

Effect of Organic and Inorganic Nutrient Sources on Total and Graded Yields of Potato in the Jos Plateau of Nigeria

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Three field trials conducted from 1983 to 1985 compared the performance of two potato cultivars (Nicola and Cardinal) under sole or mixed application of inorganic fertilizer, poultry manure, and cow dung. Each application contained equivalent amounts of N and P_2O_5: about 100 kg ha of each (recommended rate in the area). In the 3 years, poultry manure significantly out-yielded cow dung for both cultivars. The addition of 50% of the applied nutrient in the form of inorganic manure to either poultry manure or cow dung significantly improved their effectiveness in all years except 1984, which showed an 18.5% decline in total tuber yield. For both varieties, inorganic fertilizer plus poultry manure produced 21.4 and 30.1% increases in total tuber yield in 1983 and 1985, respectively. Equivalent values for inorganic fertilizer plus cow dung were 31.7, 48.3, and 105% for 1983, 1984, and 1985, respectively. Besides reducing tuber yield, the application of cow dung increased weediness. Inorganic equivalents of poultry manure and cow dung produced yields that were similar to those of both organic manures in 1983 and 1984, and were higher in 1985. This study suggests that the application of poultry manure alone or together with inorganic fertilizer can significantly increase potato yields in the Jos Plateau of Nigeria.

Fertilizer-Placement Method for Sweet Potato (*Ipomoea batatas*)

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Two N–P–K fertilizers (a mixture of 45 kg N/ha, 15 kg P/ha, and 70 kg K/ha, and a 10:10:20 mixed fertilizer applied at a rate of 700 kg/ha) were used to compare four fertilizer-placement methods (ring, side band, broadcast, and furrow). In 1984 and 1985, fertilizers were applied 6 weeks after planting to sweet potato (*Ipomoea batatas* (L.) Lam). Significant yield differences as a result of fertilizer and placement methods were observed. Fresh tuber yield increases of 82.5, 74.5, 69.6, and 46.7% were observed for the broadcast, ring, side-band, and furrow methods, respectively. The superiority and advantages of the broadcast placement are discussed.

Source–Sink Relationships in Sweet Potato (*Ipomoea batatas*)

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Relationships between storage root dry weight and vine dry weight, storage root number, and harvest index were determined from yield, date of harvest, and spacing trials. Source, sink, and partitioning rates changed during the growing season and differed among cultivars and groups of cultivars. Under Maryland conditions, vine effects predominated over storage root effects in terms of their effects on root yield and partitioning rates. Cultivars and groups of cultivars showing strong storage root effects were generally lower yielding.

COCOYAM AND MINOR ROOT CROPS BREEDING AND AGRONOMY

COCOYAM AND THE AFRICAN FOOD CRISIS

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Cocoyams (*Xanthosoma* spp. and *Colocasia* spp.) are an important group of tropical root crops, providing food energy for about 200 million people. In Africa, cocoyam is usually intercropped. The major constraints to cocoyam production are as follows: poor supply of plantable setts; field diseases (especially root rots); storage rots (which limit transportation); and sensitivity of some cultivars to calcium oxalate. In Nigeria, collar rot (*Corticium rolfsii*) is the main disease; in Cameroon, the major disease is a root rot caused by the fungus *Pythium myriotylum*. The incidence of both rots reaches 90% in many areas. Research has shown that improved cultural practices minimize the effects of rots in Nigeria and Cameroon, and that fungicide (Metalxyl) control of *Pythium* spp. is possible in Cameroon. Plantable sett production and hybridization work is in progress in Cameroon and herbicides are effective in weed control. The potential of cocoyams for alleviating the African food crisis has been examined. Their capacity for energy production is the highest among tropical root crops, and they can be consumed in a variety of forms. The protein of *Colocasia* is the highest in total and sulphur-bearing amino acids, and its starch is highly digestible and, thus, is a potential baby food.

Cocoyams (*Colocasia* spp. and *Xanthosoma* spp.) are an important group of tropical root crops; they are produced and consumed as a staple food by about 200 million people. The total world cocoyam production was estimated at 5×10^6 t in 1983 (Table 1), with more than half of that production (3.4×10^6 t) from Africa. Nigeria is the world's largest producer of cocoyams, 2.0×10^6 t, followed by Ghana, 1.4×10^6 t (Horton et al. 1984). The cocoyam output in Cameroon was 1.8×10^6 t in 1976/77 and 0.8×10^6 t in 1980/81 (Cameroon Ministry of Agriculture 1981).

Many developing countries depend heavily on root crops to feed their people. In Zaire, for example, over 50% of the total caloric intake comes from cassava. In Côte d'Ivoire, yams and cocoyams are responsible for 20% of all food energy. The production of cocoyams increased substantially in Africa between 1965 and 1981 but declined in other regions over the same period (Table 2). Cocoyam research and development has been meager compared with other tropical root crops (D.G. Coursey, personal communication, 1983; Wang and Higa 1983). In Africa, the International Institute of Tropical Agriculture (IITA) and National Research Programmes, are responsible for cocoyam research.

Table 1. Annual production ($\times 10^6$ t) of root and tuber crops.

	Potato	Cassava	Sweet potato	Yam	Cocoyam
Africa	5.0	46.8	5.0	18.7	3.4
Developing countries	49.9	121.2	105.9	19.0	4.4
Rest of world	225.8	122.2	107.3	19.2	5.0

Source: Adapted from Horton et al. (1984), Chandra (1984), and FAO (1974, 1980).

This paper reviews the potential of, and constraints to, cocoyam production, research objectives and achievements during the early 1980s, and the past and future contributions of cocoyams toward alleviating the African food crisis.

COCOYAM PRODUCTION POTENTIAL

There is considerable taxonomic confusion between the genera *Xanthosoma* and *Colocasia*. *Xanthosoma* spp. reach heights between 1 and 2 m and have short stems, large stalks, and sagittate or hastate leaves; inflorescences are rare. A corm is produced at the base of the plant and often bears more than four cormels. *Colocasia* is a corm-bearing

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Table 2. Production of root crops in developing market economies (1979/81) and changes in production from 1961 to 1984

Region	Potato	Sweet potato	Cassava	Yam	Cocoyam
			Production ($\times 10^6$ t)		
Africa	3	5	46	21	3.4
Far East	11	7	36	0	0.0
Latin America	10	2	30	0	0.0
Near East	6	0	0	0	0.0
			Change in production (%)		
Africa	129	24	43	33	58
Far East	114	−9	109	−33	−22
Latin America	40	−27	16	128	−16
Near East	138	21	−90	−33	−12

Source: Adapted from Horton et al. (1984).

perennial plant; it is usually tall, with large cordate leaves, which are variable in size and colour; inflorescences are abundant. A corm surrounded by many cormels is produced at the base of the plant. In both genera, female and male flowers are located at the base and upper region of the spadix, respectively; they are separated by a zone of infertile flowers. Chromosome numbers in *Colocasia* spp. vary from 14 to 42 (Sharma 1956; Plucknett et al. 1970). *Xanthosoma* is diploid ($2n = 26$) (Marchant 1971).

Cocoyams are grown in tropical and subtropical areas, mainly in the Pacific and Caribbean islands and in West Africa (Plucknett et al. 1970; Nzietchueng 1985). The tropics is that region of the world between the tropics of Cancer (23°30′ N) and Capricorn (23°30′ S); however, suitable environments for tropical crops are not restricted to the tropics. Plant growth environments are mainly determined by the amount and distribution of rainfall and incident solar radiation, which, in turn, determines temperature. In less-developed tropical agricultures with poor resources, the environment more often influences productivity than in more-developed temperate agricultures.

Root and tuber crops now receive research attention because some can tolerate marginal farm conditions. *Colocasia* can be grown in hydromorphic soils or under flood conditions (Plucknett and de la Pena 1971). *Xanthosoma* thrives on hydromorphic soils and tolerates upland conditions with an annual rainfall as low as 1000 mm and a wide range of soils, from those with a high aluminum content to those composed mostly of coral rock (Horton et al. 1984).

The physiological determinants of yield in cocoyams have been studied (Enyi 1968, 1977; Ezumah and Plucknett 1977; Sivan 1980). In both *Colocasia* and *Xanthosoma*, leaf area index (LAI) is positively correlated to corm and cormel yields. The leaf orientation and petiole length and angle are also important (Wilson 1984).

Colocasia is grown as a staple food crop in South Pacific areas, but is a commercial crop in Fiji, Hawaii, the Philippines, Samoa, and Tonga (Plucknett et al. 1970; Watson 1979; de la Pena and Melchor 1984). In Hawaii, with heavy fertilization *Colocasia* yields up to 50 t/ha (de la Pena and Plucknett 1967). Under tropical peasant farming, *Colocasia* yields are very low (Campbell and Gooding 1962). In Nigeria, cocoyam yields are estimated at 6 t/ha (Phillips 1976); in Cameroon, 1.4 t/ha (Cameroon Ministry of Agriculture).

Cocoyam Cultivation in Africa

Colocasia originated in Southeast Asia and was introduced to Africa through Egypt, where it has been known for over 2500 years. It was then spread along the east coast of Africa and across the continent to West Africa (Plucknett et al. 1970). *Xanthosoma* originated in tropical America and was introduced to West Africa by Indian missionaries around 1840 (Purseglove 1972; Doku 1980; Nzientchueng 1985).

Cocoyams are mainly cultivated by peasant farmers in West Africa, especially in Cameroon (Lyonga 1979; Nzietchueng 1985), Ghana (Karikari 1971), and Nigeria (Knipscheer and Wilson 1980). Cocoyams are usually intercropped; therefore cropping practices are dependent upon those of the other crops. The cropping practices of these crops, in turn, are influenced by the agroecology and consumer habits (Coursey 1968; Knipscheer and Wilson 1980; Onwueme 1984; Igbokwe et al. 1984; Karikari 1984).

In addition to the lack of improved setts and cultural practices, recent studies (Arene and Okpala 1981; Okeke 1980; Nzientchueng 1983a, 1985) show that field and storage rots are the major constraints to cocoyam production in Africa. Other constraints include weeds (Abasi and Onwueme 1984) and relate to the long maturation of cocoyams. Because of tuber irritancy, some cultivars of cocoyam are not safely eaten until thoroughly cooked (Coursey 1984). In the last 10 years, IITA and National Research Programmes in Africa have made some progress in these problem areas.

Research Highlights and Achievements

Low cocoyam yields in Africa are mainly attributable to disease (Arene and Okpala 1980; Nzietchueng 1985). The major diseases are cocoyam

disease (*Corticium rolfsii*) in Nigeria and root rot disease of *Xanthosoma* (*Phythium myriotylum*) in Cameroon; both reduce yield by up to 90%. Cocoyams are also liable to weed infestation (Abasi and Onwueme 1984).

Recent research in Nigeria (Arene and Okpala 1981) has revealed that it is possible to control cocoyam disease (*Corticium rolfsii*) through improved cultural techniques (e.g., hilling and deep planting). In Cameroon, Nzietchueng (1983b) reported that the root rot disease of *Xanthosoma* (*Pythium myriotylum*) can be controlled with a fungicide (Metalaxyl); still, selection for root rot resistance in Cameroon is ongoing. In fact, techniques for floral induction with gibberellic acid (IITA 1978, 1979, 1980; Agueguia and Nzietchueng 1984) now enable hybridizational breeding in *Xanthosoma* and *Colocasia* (CNRCIP 1980, 1981, 1982, 1983; Wilson 1984). Herbicide use is effective for controlling weeds in *Xanthosoma* cultivation in Nigeria (Abasi and Onwueme 1984).

The Role of Cocoyams in Alleviating the African Food Crisis

Tropical root crops were essentially products of subsistence agriculture until 20–30 years ago; changes are now evident. Over the last 15 years, with the exception of the Near East, root crops production has expanded (Table 2) (Horton et al. 1984; Plucknett 1984). Root crops are now being considered as a source of energy. There is interest in cassava as a source of alcohol and *Colocasia* has received similar attention (Wang et al. 1984).

In developing countries, the production of all root crops increased by 44% from 1961 to 1980 (CIP 1982; Plucknett 1984). In Africa, the output of cassava now exceeds the combined output of all other root crops (Terry et al. 1981; Coursey 1984). Mazumdar's (1980) estimates of the need for supplementary food of some African countries between 1972 and 1985 show that, except for Burkina Faso and Kenya, their food needs are higher for roots and tubers than for cereals (Table 3).

Table 3. Supplementary food needs ($\times 10^3$ t) of 10 African countries between 1972 and 1985.

Country	Cereals	Roots and tubers
Angola	214	754
Benin	127	330
Burkina Faso	1786	365
Kenya	850	482
Liberia	768	1575
Mozambique	322	1128
Nigeria	3517	9890
Tanzania	352	588
Uganda	80	452
Zaire	407	4700

Source: Mazumdar (1980).

Cocoyams are a staple in certain regions of some African countries (Lyonga 1979; Karikari 1984; Nzietchueng 1985). Corms and cormels may be eaten boiled, mashed, pounded, alone or mixed with other starchy staples (e.g., plantain), or grated and incorporated into soups and stews. The youngest leaves of several cultivars are consumed as constituents of either soups or salads. In the Caribbean islands, one species, *Xanthosoma brasiliense*, is grown essentially for its leaves, which are used in salads (Morton 1972).

Many varieties of *Colocasia* and *Xanthosoma* are valuable because most parts of the plant may be used for food. The tubers provide easily digested starch, and the leaves are consumed as green vegetables. Cocoyam leaves have a high thiamine content (Morton 1972), which is an advantage in modern diets where a lot of refined carbohydrate is consumed (as in Burkina Faso; Table 3). *Colocasia* leaves are an excellent source of folic acid, riboflavin, and vitamin A, particularly valuable to anemics. The food-energy yield of cocoyams per unit land area is high (Parkinson 1984), and the protein in *Colocasia* is richer in

Table 4. Nutrients obtained from a daily, per-capita consumption of 2 kg of prepared food based on roots and tubers.

Food	Protein (g)	Energy (kJ)	Protein (% kJ)	Amino acids (g/100 g protein)		
				Lysine	Methionine	Cysteine
Cassava	20	11553	3.0	2.9	0.7	0.0
Yam	30	8540	6.5	4.5	1.2	0.2
Sweet potato	20	9042	3.8	4.6	1.5	0.0
Taro	44	7535	9.8	4.2	1.1	0.4
Protein[a]				4.2	2.2	2.2

Source: Adapted from Splittstoesser et al. (1973) and Parkinson (1984).
[a]Reference protein of the Food and Agriculture Organization.

total and sulfur-bearing amino acids than that of other root crops (Table 4) (Splittstoester et al. 1973; Parkinson 1984).

CONCLUSIONS

For cocoyams to contribute significantly toward alleviating the African food crisis, the following actions are imperative.

- Research on cocoyam, which has hitherto been neglected, when compounded with research on other root crops, must be intensified with emphasis on disease control, farming systems, storage, processing, and marketing.
- Producers must cooperate with researchers; current approaches now involve farmers in applied research. Therefore, on-farm adaptive research should be encouraged.
- The hydromorphic soils and conditions that are being exploited for paddy rice should be tried for growing *Colocasia*, a crop that can lend itself to complete mechanization (as in Hawaii).
- To facilitate meaningful research and development work on cocoyam and other root crops, cooperation between international centres and national programs is essential.

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GINGER RESEARCH IN NIGERIA

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Nigeria was an important producer and exporter of dried ginger until 1967, when production declined. Since 1982, efforts have been intensified through research to improve production. Efforts to cross the two varieties of ginger available in Nigeria have been unsuccessful. Ginger grows in both derived savanna and rainforest areas and is favoured by mulching. The highest yields are achieved by planting 20-g setts at 20 cm × 20 cm at the beginning of the rains. Trade surveys indicate that the demand for ginger is currently high and will remain so into the foreseeable future.

Ginger is an underground stem or rhizome of *Zingiber officianale*, a herbaceous perennial plant that is usually cultivated as an annual. When freshly harvested, ginger consists of tangled clumps of interconnected rhizomes, known as "races" or "hands," and branches, known as "fingers."

Ginger originated in Southeast Asia and was successfully introduced into a large number of tropical and subtropical countries like Nigeria, which have since become major producers and exporters of the root. Ginger is marketed through three main channels: spice trade, confectionery trade, and vegetable trade. The marketing channel used depends on the form in which the ginger reaches the market (Table 1). The dried forms of ginger are the most important in international trade (Table 2).

Nigeria started ginger cultivation in 1927 and has since become prominent world-wide as a producer and exporter of dried ginger; however, there have been substantial variations in production levels. In 1963/64, 1964/65,1965/66, and 1966/67, the Northern Nigeria Marketing Board purchased 3800, 2800, 1650, and less than 300 t of ginger, respectively (Anand 1982). Today, the Nigerian Groundnut Board is responsible for marketing ginger. However, since 1978, no export value has been available (Table 3); yet, the 1986 United Kingdom price for Nigerian ginger is GBP 600/t (in January 1987, 0.64 pounds sterling [GBP] = 1 United States dollar [USD]). Thus, the 1977 export of 3000 t was worth GBP 1 800 000. Ginger, therefore, is an important export for Nigeria.

Recognizing this, the Nigerian Groundnut Board is cooperating with the Kaduna State Government (the traditional home of ginger cultivation in Nigeria) to promote ginger production. The Board now offers higher prices to producers and the State Government intends to set up a ginger-processing plant with aid from the Nigerian Industrial Development Bank (NIDB). Because ginger production lacks scientific bases, in 1982, the Nigerian Groundnut Board contacted the National Root Crops Research Institute (NRCRI) at Umudike about doing agronomic research to improve production. Recently (1984), NIDB asked NRCRI to ascertain the research base available to support the ginger-processing plant it intends to finance.

This paper reviews ginger research since 1982 and suggests future directions for research on ginger production and processing in Nigeria.

GERM PLASM

Surveys in 1982 showed that only two varieties of ginger are grown in Nigeria: yellow ginger (*tafin giwa*, "elephant foot") and black ginger (*yatsum biri*, "finger of monkey"). Both varieties are primarily grown in the Jebba District of Kaduna State and, because of their high yields, are preferred by processors of ginger oil and oleoresin (Anand 1982). The highly pungent flavour of their oleoresin is also desired by meat processors. Efforts to broaden the genetic base with varieties from India and Sierra Leone have been unsuccessful.

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Table 1. Forms of ginger in commerce.

Form	Description	Trade channel[a]
Dried ginger		
Peeled, scraped, or uncoated	Cork skin cleanly removed without damage to the underlying tissue	S and C
Rough scraped	Cork skin partly removed, usually only on one side	S and C
Unpeeled or coated	Skin remains intact	S and C
Black ginger	Scalded 10–15 min in boiling water and dried	S and C
Bleached or limed	Clean peeled and treated with lime as sulphorous acid	S and C
Split or sliced	Unpeeled or unscraped but longitudinally split or sliced	S and C
Preserved ginger	Prepared at 5–7 months, peeled, cut into pieces, and impregnated with sugar syrup	S and C
Fresh ginger	Raw	V
Ground ginger[b]	Dried and ground	S and C
Essential oil and oleoresin[b]	Extracts	C and P

Source: Adapted from Anand (1982).
[a]S, spice; C, confectionery; V, vegetable; P, perfumery.
[b]Gradually increasing in world market share.

Table 2. Major producers of fresh, preserved, and dried ginger.

Fresh	Preserved	Dried
Brazil	Australia	Australia
Fiji	China	China
Mauritius	Hong Kong	India
West Indies		Indonesia
		Jamaica
		Mauritius
		Nepal
		Nigeria
		Sierra Leone

Source: Adapted from Anand (1982).

Breeding

Ginger does not flower in the area where it is traditionally grown (southern Zaria), but both varieties flower profusely under rainforest conditions at Umudike (Imo State) and Igbariam (Anambra State). The flowering has been studied (NRCRI 1983, 81), but no successful crosses have been made. This has been attributed to the arrangement of the major bracts in an inflorescence that provides receptacles to store rainwater in their axils and this predisposes flowers to pest attack and fungal rot.

Ecological Trials

In 1982, ginger was shown to grow outside the known growing area of southern Zaria without change in the essential export or consumer qualities (NRCRI 1982). Consequently, in 1983, the adaptability of ginger to different ecological zones was tested. Results showed that, except at Igbariam, there were no significant responses to fertilizer at Umudike, Otobi, or Kubacha for both ginger varieties (Table 4) (NRCRI 1983, 79–80). At Umudike and Kubacha, yellow ginger significantly ($P = 0.05$) out-yielded black ginger; at Igbariam and Otobi, there was no significant difference in yield. The low yield at Otobi may relate to the poor quality of seed materials. This trial suggests that both varieties of ginger are adapted to ecological zones other than southern Zaria.

Cultural Management

Fertilization

Ginger requires heavy manuring wherever it is grown. In Nigeria, manuring of the crop is still based on the traditional use of organic fertilizer (e.g., cow dung). Because of the unpredictable availability of organic fertilizer, inorganic fertilization, which is becoming more readily available in Nigeria, must be introduced.

In 1983, trials at Umudike (rainforest) and Kubacha, southern Zaria (savanna) determined the response of yellow ginger to N, P, and K application (NRCRI 1983, 80–81): 0, 45, and 90 kg N/ha as ammonium sulphate; 0, 15, and 30 kg P/ha as triple superphosphate; and 0, 90, and 180 kg K/ha as muriate of potash were combined in a factorial experiment and replicated three times in each of the two locations. There were no significant responses to N–P–K fertilizer at either location. Mean yields at Umudike and Kubacha were 15.3 and 13.9 t/ha, respectively.

Table 3. Annual export (t) of dried ginger in selected countries.

	1960–68 (average)	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
India[a]	5103	1717	1223	3156	6746	6050	5083	4681	4786	4461	8359	11796
Jamaica	673	279	305	326	348	479	336	286	535	213	(172)	NA
Nepal[a]	NA	NA	NA	NA	NA	637	154	177	263	287	283	71
Nigeria	1893	3238	3783	2347	2084	1141	630	664	1927	3071	NA	NA
Sierra Leone	780	758	440	601	489	348	NA	NA	NA	NA	NA	NA

Notes: NA, not available. The value in parentheses is an estimate.
Source: Adapted from Anand (1982).
[a]For India and Nepal, years refer to the 12-month period ending 31 March.

Table 4. Mean yield (t/ha) of ginger at four locations.

	Umudike		Igbariam		Otobi		Kubacha	
Variety	F[a]	NF[a]	F	NF	F	NF	F	NF
Yellow	13.6	13.2	22.7	18.5	5.3	3.4	12.8	12.6
Black	9.8	9.1	22.5	17.1	5.2	4.0	9.7	9.6
LSD ($P = 0.05$)	2.2		3.8		NS		2.01	

Note: NS, not significant.
F, fertilizer; NF, no fertilizer.

Table 5. Effect of mulch on the yield (t/ha) of yellow and black ginger.

Mulch	Yellow	Black	Mean
Grass	16.9a	15.5a	16.2a
Broad-leaved	14.3b	12.0b	13.2b
No mulch	13.5b	6.7c	11.1c
Mean	14.9b	11.4b	

Note: Values in the same column followed by the same letter are not significant at $P = 0.05$ by Duncan's multiple-range test.

Table 6. Effect of land preparation, mulch, and spacing on the yield of yellow and black ginger.

	Ridge				Flat			
	10 cm[a]	20 cm	30 cm	Mean	10 cm	20 cm	30 cm	Mean
Yellow ginger								
Mulch	33.5	23.3	27.4	28.1	30.6	22.2	12.6	21.8
No mulch	24.5	14.5	11.3	16.8	23.7	13.7	17.1	18.2
Black ginger								
Mulch	27.9	21.9	21.1	23.6	24.8	15.1	16.7	19.2
No mulch	15.8	8.8	6.2	10.2	15.4	9.8	9.7	11.3

Note: LSD ($P = 0.05$) = 9.0.
Source: Umudike (1983).
[a]Spacing interval.

Effect of Mulch Type

Heavy mulching favours ginger production. Because ginger grows and produces similar-quality rhizomes in areas other than the known growing area of southern Zaria, and because locally available mulch materials vary, the effect of different mulch materials on ginger yield was investigated (NRCRI 1983, 79–80). In general, mulching significantly ($P = 0.05$) enhanced the yields of both varieties (Table 5). Grass mulch was significantly ($P = 0.05$) better than broad-leaved mulch, and this difference was more evident in black ginger. The differences among mulch types were attributed to delayed sprouting without mulch, erratic sprouting with broad-leaved mulch, and even and early sprouting under grass mulch.

Effects of Spacing, Land Preparation, and Mulch

The effects of spacing (10, 20, and 30 cm), land preparation (ridges and flats), and mulch were evaluated on the two varieties of ginger in 1982 and 1983 (NRCRI 1983, 82). The highest yields were obtained under mulch for both ridges and flats at 10-cm spacing. Wider spacing decreased yields. Nonetheless, results showed that ginger can grow on ridges or flats. Ridges may be used in fadama areas (Table 6).

Table 7. Effect of planting time, seed weight (g), and spacing (cm) on yield (t/ha) and output–input ratio of yellow and black ginger.

	20-g seed			30-g seed			40-g seed			Mean yield
	20 cm	30 cm	40 cm	20 cm	30 cm	40 cm	20 cm	30 cm	40 cm	
Yellow ginger										
Planting time										
April	18.0	9.0	3.1	23.5	12.8	10.1	25.0	15.9	9.0	14.0
May	6.0	5.5	2.8	14.3	5.5	3.9	12.5	6.8	4.1	6.8
Mean yield	12.0b	7.3bc	3.0c	18.9a	9.2b	7.0b	18.8a	11.4b	6.6bc	
Equivalent input (t/ha)	5.0	4.0	2.5	7.5	6.0	3.2	10.5	8.0	5.0	
Output–input ratio	2.5	1.8	1.2	2.5	1.5	2.2	1.8	1.4	1.3	
Black ginger										
Planting time										
April	21.7	10.3	6.8	24.3	13.8	7.9	28.3	15.6	9.9	15.4
May	10.5	5.3	3.7	13.8	7.6	4.8	14.8	8.8	4.4	8.2
Mean yield	16.1a	7.8b	5.3b	19.1a	10.7b	6.4b	21.6a	12.2b	7.2b	
Equivalent input (t/ha)	5.0	4.0	2.5	7.5	6.0	3.8	10.5	8.0	5.0	
Output–input ratio	3.2	2.0	2.1	2.5	1.8	1.7	2.1	1.5	1.4	

Note: Mean yields followed by the same letter(s) are not statistically significant at $P = 0.05$ by Duncan's multiple-range test.
Source: Adapted from Omenukor (1983).

Table 8. Nigerian exports (t) of dried ginger by regional destination and year.

	1960–68 (average)	1969	1970	1971	1972	1973	1974	1975	1976	1977
Europe	1359	1888	2541	1777	1448	914	261	268	1384	1971
United Kingdom	802	1064	1742	951	415	550	87	198	1262	634
Other Western European countries	557	824	799	826	1033	364	174	68	122	1337
Eastern Europe	—	—	—	—	—	—	—	2	—	—
North America	564	1169	1207	508	603	227	376	396	543	1100
United States	546	1169	1207	508	601	224	376	396	543	1100
Canada	18	—	—	—	2	3	—	—	—	—
Middle East	—	—	20	16	—	—	—	—	—	—
Asia	39	91	—	25	8	—	—	—	—	—
Other countries	168	90	15	21	25	—	—	—	—	—
Total	2130	3238	3783	2347	2084	1141	637	664	1927	3071

Source: Adapted from Anazia (1982).

Effects of Spacing, Seed Weight, and Time of Planting

Although it has been shown that wide spacing decreased yields (NRCRI 1983, 82), it is still necessary to determine the input–output ratio for economical seed rate. R. Omenukor (NRCRI 1983, 81) studied the effect of spacing, seed weight, and time of planting on the yield of both varieties of ginger and showed that all three factors significantly affected yields ($P = 0.05$). The output–input ratio was maximized with 20-g seed planted at 20 cm × 20 cm spacing in April (Table 7).

Ginger Oil and Oleoresin Extraction

Presently, food manufacturers and spice consumers prefer sterile extracted spices (ginger oil and ginger oleoresin) and such products are now regular commodities in international trade with India, Indonesia, and Singapore as the major producers and exporters. In 1982, however, we proposed in collaboration with the Department of Chemical Engineering, Ahmadu Bello University, Zaria, Nigeria, to investigate the potential of ginger processing in

Nigeria. Execution of the proposals has not yet commenced.

FUTURE PROSPECTS

Systematic research on ginger in Nigeria is about 3 years old. It is evident that the previous low production of ginger will be improved. The demand for ginger products exists (Table 8) and we need multidisciplinary research to increase ginger output and help to "ginger up" Nigeria's economy.

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ABSTRACTS

EFFECT OF SETT SIZE, SETT SOURCE, AND PLANT DENSITY ON THE MULTIPLICATION RATIO OF COCOYAMS

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Traditionally, cocoyams, *Xanthosoma sagittifolium* and *Colocasia esculenta*, are propagated vegetatively with corms and cormels, resulting in a low multiplication ratio of 1:5. Trials conducted in 1983 and 1984 showed that sett size, sett source (corm or cormel), and plant density influenced the multiplication ratio. Total yield in *C. esculenta* was significantly ($P = 0.05$) highest using 20-g setts, corms as the sett source, and a density of 100 000 plants/ha. In *X. sagittifolium*, total yield was significantly ($P = 0.05$) highest with 30-g setts and a density of 75 000 plants/ha, irrespective of sett source. The highest multiplication ratio (1:18) for *C. esculenta* was obtained with 20-g setts and a density of 50 000 plants/ha. For *X. sagittifolium*, the highest multiplication ratio (1:23) was obtained with 10-g setts and a density of 50 000 plants/ha.

THREE NEW DISEASES OF COCOYAM IN TANZANIA

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A survey of cocoyam diseases in Tanzania uncovered three new diseases: dark leaf spot, caused by the *Colletotrichum* state of *Glomerella cingulata* (Stonem.) Spauld and Schrenk; bacterial leaf blight, caused by *Xanthomonas campestris* L. (probably subspecies *dieffenbachiae* [McCullock and Pirone]); and root rot. The etiology of the root rot appears complex, involving *Fusarium solani* and *Meloidogyne* spp.

EFFECT OF LEAF HARVESTING AND SPACING ON THE YIELD OF *XANTHOSOMA SAGITTIFOLIUM* AND *COLOCASIA ESCULENTA*

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From the sixth leaf stage onwards, three leaf-harvesting treatments were imposed on *Xanthosoma sagittifolium* and *Colocasia esculenta* planted at three densities: 1 × 1 m, 1 × 0.75 m, and 1 × 0.5 m. The leaf-harvesting treatments were as follows: control (no leaf harvest), alternate defoliation (harvesting of every other new leaf), and complete defoliation (harvesting of all new leaves). In *X. sagittifolium*, leaf harvesting resulted in a significant reduction in cormel yield. Alternate and complete defoliation reduced cormel yield 31.4 and 58.6%, respectively. Corm yield, corm size, and cormel size were not significantly affected by leaf harvesting. In *C. esculenta*, leaf harvesting had no significant effect on corm yield. Corm size and number of

suckers were significantly affected; however, there was no clear trend. Cormel yield was significantly higher at the narrowest spacing (1 × 0.5 m) in *X. sagittifolium*. The 1 × 0.75 m and 1 × 0.5 m spacings gave yields 18.2 and 59.6% higher, respectively, than the 1 × 1 m spacing. Spacing had no significant effect on the number of cormels per plant, the corm yield, or the size of the corm; cormel size, however, was significantly reduced at the narrowest spacing (1 × 0.5 m) in *X. sagittifolium*. In *C. esculenta*, spacing had no significant effect on corm yield, but there was a 30.1% reduction in corm yield at the narrowest spacing (1 × 0.5 m) compared with the widest spacing (1 × 1 m).

ROOT CROPS PROTECTION

BIOLOGICAL CONTROL OF THE CASSAVA MEALYBUG (*PHENACOCCUS MANIHOTI*) BY THE EXOTIC PARASITOID, *EPIDINOCARSIS LOPEZI*

P. NEUENSCHWANDER, W.N.O. HAMMOND, AND H.R. HERREN[1]

Since its accidental introduction into Africa, the cassava mealybug (CM; *Phenacoccus manihoti* Mat.-Fer.) has spread through about 70% of the cassava belt. From South America, the area of origin of CM, the specific parasitoid *Epidinocarsis lopezi* (De Santis) was introduced into Nigeria. Since 1981, it has been released in 12 countries. The potential efficiency of *E. lopezi* is exhibited by its remarkable spread and establishment. By December 1985, the parasitoid was established in 13 African countries covering 650 000 km^2. In southwestern Nigeria, the CM population declined after the two initial releases and stayed low. During the same period, populations of indigenous predators of CM, mainly coccinellids, and indigenous hyperparasitoids of *E. lopezi* declined because of a reduced supply of food and hosts, respectively. The efficiency of *E. lopezi* was investigated experimentally by physical and chemical exclusion methods. In two sleeve cage experiments, CM populations were 7.0 and 2.3 times lower on artificially infested cassava tips covered with open sleeves than on cassava tips with closed sleeves, which excluded natural enemies. Similarly, CM populations were higher in fields where parasitoids were excluded chemically than in fields with natural enemies (200 vs 10 per tip). These results are discussed in view of the special suitability of biological control for subsistence farming in Africa.

In March 1973, an unknown species of mealybug was reported causing serious damage to cassava near Brazzaville, Congo (Sylvestre 1973; Matile-Ferrero 1978) and in Kinshasa, Zaire (Hahn and Williams 1973). From this area, the new pest spread quickly through tropical Africa, causing estimated root yield losses of 84% (Herren 1981; Nwanze 1982). Within a short period, this insect became the major pest of cassava. The cassava mealybug (CM) eventually was described as a new species, *Phenacoccus manihoti* (Matile-Ferrero 1977), presumably of South American origin.

In 1980, a project for the biological control of CM was initiated (Herren 1982). In 1981, CM was discovered in its native home in Paraguay by A.C. Bellotti of the International Centre for Tropical Agriculture in Cali, Colombia. Subsequent explorations in Paraguay and Brazil resulted in the discovery of a complex of natural enemies (Yaseen 1982; Loehr and Varela 1982), including the parasitoid *Epidinocarsis lopezi* (De Santis). The wasps were quarantined by the Commonwealth Institute of Biological Control in London, and taken through the Nigerian quarantine to the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, for biological studies and multiplication. This procedure followed the existing guidelines and was subsequently approved by the Inter-African Phytosanitary Council of the Organization of African Unity. The first releases were made in 1981 on the IITA campus, and establishment was first reported by Herren and Lema (1982). Early encouraging results on the reduction of CM populations in two release fields (Herren and Lema 1982; Lema et al. 1983; Lema and Herren 1985) led to the initiation of the Africa-wide Biological Control Project (ABC-P). The present paper reviews the activities of ABC-P on *E. lopezi*.

THE SPREAD OF THE CASSAVA MEALYBUG

While releasing and monitoring *E. lopezi*, the continuing spread of CM into 27 of the 35 African cassava belt countries was observed (Fig. 1). Based on scattered observations and available records, the spread of CM originated from five or six foci: Congo–Bas-Zaire, 1973; Shaba (Zaire), 1976; Gambia–Senegal, 1976; Nigeria–Benin, 1979; Kivu (Zaire), 1982; and perhaps Sierra Leone, 1985. Today, the eastern and southern distribution limits of CM are the Rift Valley in Rwanda (altitude, 1500 m) and the northern half of Zambia, respectively. Most recently, heavy CM outbreaks were reported in Malawi, and the pest may have spread to Tanzania and Mozambique. Along the West African coast,

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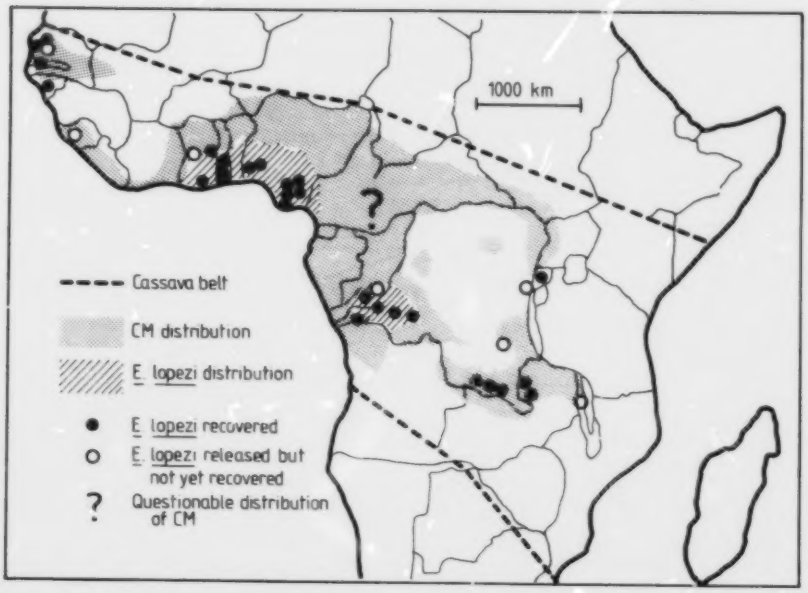

Fig. 1. *Distribution of the cassava mealybug (CM) and* Epidinocarsis lopezi *in Africa (Herren et al. 1986).*

only Conakry, Guinea, has not yet confirmed the presence of CM outbreaks.

RELEASE, ESTABLISHMENT, AND DISPERSAL OF *E. LOPEZI*

The first releases of *E. lopezi* were made late in 1981 near Ibadan, Nigeria, and late in 1982 near Abeokuta, Nigeria. By March 1983, almost all fields sampled within 100 km of Abeokuta had *E. lopezi*, and the limit of distribution was 170 km north of the release site. The spread into the rain forest was slower. By the end of 1984, *E. lopezi* was found in 70.1% of all fields south and west of the Niger River, occupying over 200 000 km² (Fig. 2). The parasitoid was mostly found on local cassava varieties in traditional farming environments. North of the Niger River, CM populations were very low, and *E. lopezi* was recovered from only a few localities.

By December 1985, over 50 releases were made in a total of 34 areas (8000 km²) in 12 countries (Fig. 1). Successful establishment, i.e., recovery after the first rainy season following the release, was reported from the Congo, Gambia, Ghana, Guinea-Bissau, Nigeria, Rwanda, Senegal, Togo, Zaire, and Zambia. The wasp spread on its own into Angola, Benin, and Cameroon from release sites in neighbouring countries. Establishment has not yet been reported from the recent releases in Malawi and Sierra Leone. *Epidinocarsis lopezi* now occupies 650 000 km² in 13 countries (Herren et al. 1986), which places it among the fastest spreading biological control agents ever reported.

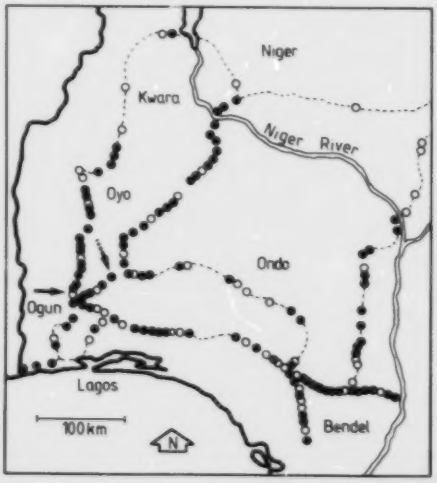

Fig. 2. *Distribution of* Epidinocarsis lopezi *in southwestern Nigeria during the fourth survey in December 1984. Solid arrow, release near Abeokuta, November 1982; broken arrow, release near Ibadan, November 1981;* ●, E. lopezi *recovered;* ○, *only CM found; broken line, no CM found. (Neuenschwander and Hammond 1986).*

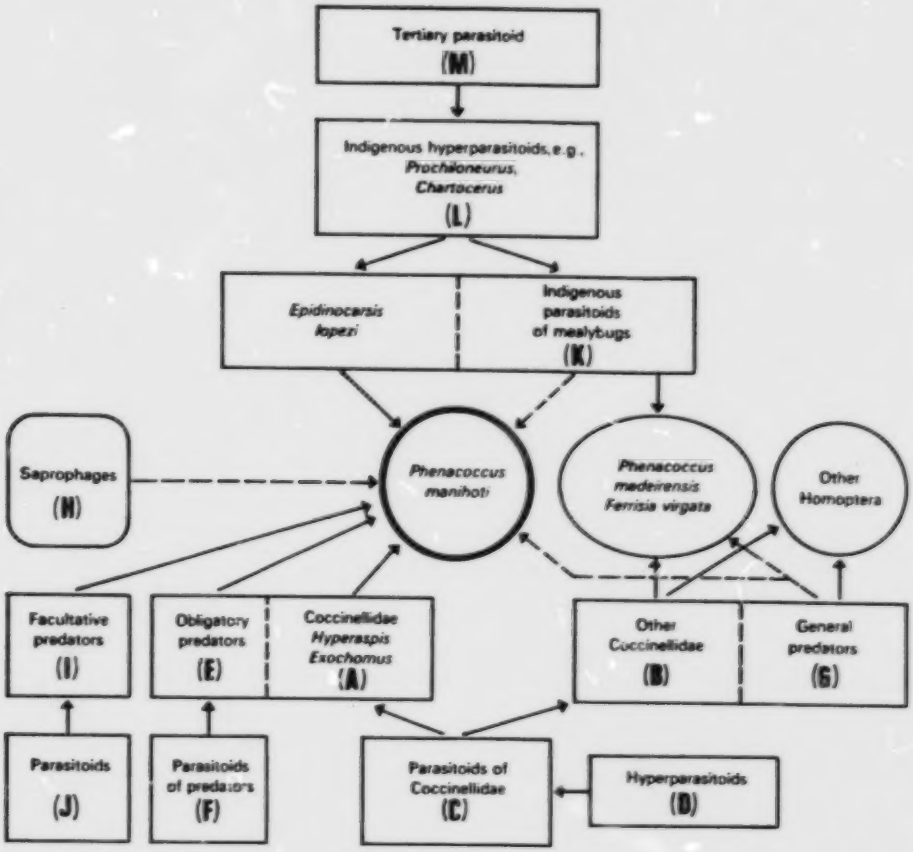

Fig. 3. *Major trophic relationships of insects associated with cassava mealybug in Africa (guilds A to M) (Neuenschwander, Hennessey et al. 1986).*

Insects Associated with the Cassava Mealybug and *E. lopezi*

Before CM was accidentally introduced into Africa, the only insects commonly found on cassava were grasshoppers and whiteflies. With the introduction of the CM, the arthropod fauna on cassava rapidly increased in abundance and complexity (Matile-Ferrero 1977; Fabres and Matile-Ferrero 1980; Akinlosotu and Leuschner 1981; Akinlosotu 1982; Boussienguet 1986). The cassava mealybug was attacked, though not controlled, by a variety of indigenous predators, mainly coccinellids. In most areas (with the exception of Gabon), indigenous parasitoids on CM were infrequent.

Following the introduction of *E. lopezi*, detailed surveys of the fauna on cassava conducted in nine countries found over 130 species of arthropods associated with CM, among which only about 20 were common (Neuenschwander, Hennessey et al. 1986). The species were grouped in 11 guilds comprising insects with similar feeding habits (Fig. 3).

A quantitative analysis of the evolution of natural enemy activity following the introduction of *E. lopezi* was done in four extensive surveys in southwestern Nigeria (Neuenschwander and Hammond 1986). The frequency of indigenous predators,

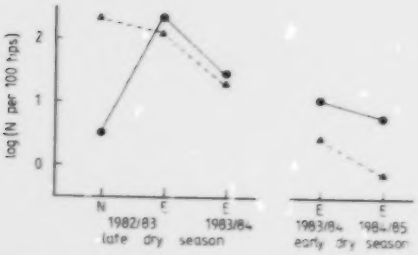

Fig. 4. *Estimated number (N) of parasitoids (●—●) and predators (▲ - - - ▲) of the cassava mealybug per 100 tips from random fields in southwestern Nigeria, from March 1983 (late dry season) to December 1984 (early dry season). N, Epidinocarsis lopezi not yet widely established; E, E. lopezi widely established. (Neuenschwander and Hammond 1986).*

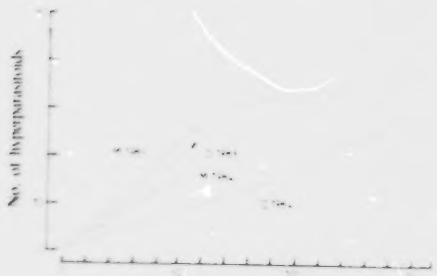

Fig. 5. *Regression between numbers of parasitized mealybugs and hyperparasitoids reared from samples of 10 bunch tops per field, from four surveys in southwestern Nigeria. M, March; D, December; solid line, linear regression; broken line, tail end of quadratic regression (Neuenschwander and Hammond 1986).*

which accounted for 98.4% of all insects caught before the introduction of the exotic wasp, fell from 190 to 0.3 per 100 randomly collected cassava tips (Fig. 4). This reduction was due to a decrease in the predators' food supply (CM) on cassava. Shortly after its introduction, *E. lopezi* (and its hyperparasitoids) already accounted for 61.5% of all associated insects. Parasitoids were even more prevalent early in the dry seasons, constituting 84–86% of all insects.

About 10 African hyperparasitoids attacked *E. lopezi* in the field. Originally they came from various species of *Anagyrus* and other primary parasitoids on related mealybugs. During each survey, they proved to have a density-dependent relationship with *E. lopezi* populations (Fig. 5). Overall, the hyperparasitism fell from 41.2% in March 1983 to 16.9% in December 1984. In spite of these hyperparasitoids, the frequency of strongly damaged cassava tips declined from 78–94% in March 1983 to 27% in December 1984.

Efficiency of *E. lopezi*

Following the introduction of this exotic wasp, the CM populations at IITA collapsed first in the release field and later in the control field, where *E. lopezi* immigrated (Herren and Lema 1982). The same pattern was observed 1 year after release in the second release field near Abeokuta (Lema et al. 1983). More important than this observation of the early collapse of the host population was, however, persistently low CM populations thereafter (Fig. 6), as was the case for the extensive surveys 1 year after release (Neuenschwander and Hammond 1986).

The efficiency of the exotic parasitoid was estimated from exclusion experiments (Hodek et al. 1972; Kiritani and Dempster 1973; van Lenteren 1980). Two types of experiments were performed at IITA (Neuenschwander, Schulthess et al. 1986). In a sleeve cage experiment late in the 1983/84 dry season, CM populations were 7 times lower on artificially infested cassava tips covered with open sleeve cages, which allowed access to beneficials, than on cassava tips covered with closed sleeves, which excluded natural enemies (Fig. 7). When this experiment was repeated early in the next dry season, the difference between the two types of sleeve cages was 2.3 times, and this was exclusively caused by *E. lopezi*. Similarly, CM populations in an artificially infested field were higher in the half that was treated 13 times with carbaryl, which selectively killed more parasitoids than CM, than in the half where *E. lopezi* reached high parasitization rates (200 vs 10 per tip) (Fig. 8).

Discussion

The data demonstrate that *E. lopezi* is capable of maintaining CM populations through most of the dry season at the low level they usually have at the beginning of the dry season. All our results concerning efficiency come from the Transition and Guinea Savanna zones of southwestern Nigeria. Similar results have recently been observed in Bas-Zaire (R.D. Hennessey, personal communication), Ghana (P. Neuenschwander and W.N.O. Hammond, unpublished), and the Luapula valley of Zambia (C. Klinnert, personal communication). More precise data are needed, however, to prove the efficiency of *E. lopezi* in the different ecological zones of

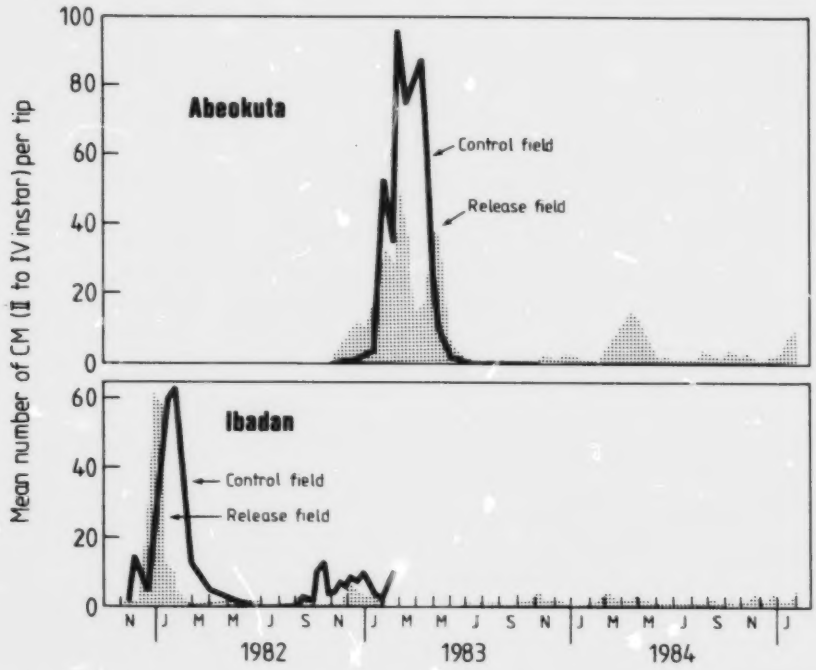

Fig. 6. *Impact on mealybug populations of the release of* Epidinocarsis lopezi *in cassava fields from 1981 through 1984, at Ibadan and Abeokuta, Nigeria.*

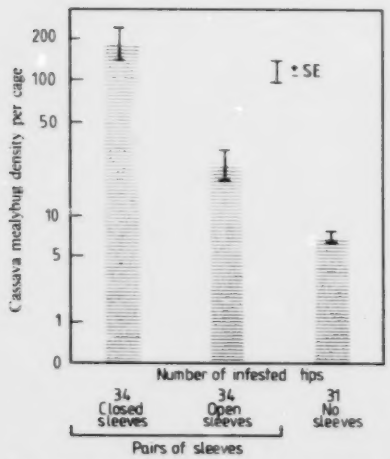

Fig. 7. *Cassava mealybug population 2 1/2 months after infestation from closed sleeves, open sleeves, and a random sample of infested tips without sleeves (Neuenschwander, Schulthess et al. 1986).*

its establishment, i.e., from the Sudan Savanna in Senegal, to the rain forest in Zaire, to the East African highlands.

The efficiency of *E. lopezi* can partly be explained by its life history and biology. This wasp has a life cycle that lasts only about half as long as the life cycle of its host (Lema and Herren 1981). In addition to the mortality it inflicts on its host through reproduction (mummy formation), *E. lopezi* also kills its host by host-feeding and mutilation (Neuenschwander and Madojemu 1986). This species has a density-dependent relationship with its host (R.D. Hennessey, personal communication; W.N.O. Hammond and P. Neuenschwander, unpublished). This is generally considered to be characteristic of an efficient parasitoid. Though some encapsulation and melanization has been observed by dissecting parasitized CM, this does not seem to reduce the efficiency of *E. lopezi* (Sullivan and Neuenschwander 1984). Life-table studies under different temperatures have been initiated (B. Loehr and A.M. Varela, unpublished), but more information on the biology and ecology of *E. lopezi* is

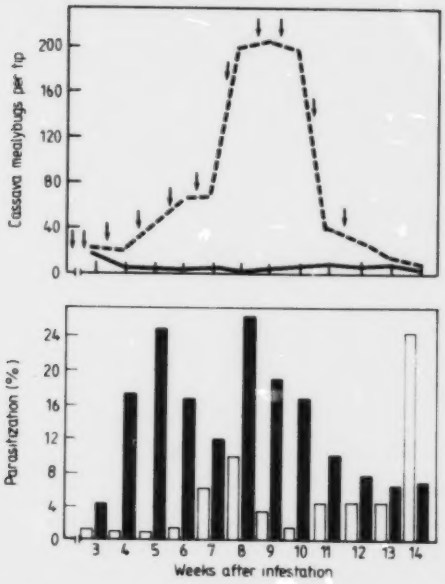

Fig. 8. *Cassava mealybug population development in insecticide-treated (broken line) and untreated (solid line) plots together with corresponding parasitization rates of* Epidinocarsis lopezi. *Arrows indicate insecticide application (spray).* □, *sprayed;* ■, *unsprayed (Neuenschwander, Schulthess et al. 1986).*

needed to enable the development of the planned computer simulation model of the third trophic level.

Despite the incompleteness of the data, the present biological control program appears successful, at least in the transitional vegetation zone. As in all classical biological control programs, the benefits from the one-time establishment of a successful parasitoid accrue over the years. The parasitoid does not need the benefit of an elaborate extension service and benefits both small- and large-scale farmers. Since subsistence farmers in particular often do not have the means for chemical control (equipment, insecticides, cash, water), biological control is more appropriate. Therefore, this alternative should be pursued more vigorously, even if the result is only partial control of the pest.

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EFFECT OF CULTURAL PRACTICES ON THE AFRICAN CASSAVA MOSAIC DISEASE AND ITS VECTOR, *BEMISIA TABACI*

G.W. OTIM-NAPE AND D. INGOOT[1]

The effects of plant spacing, planting time, and number of cassava shoots on the incidence and severity of the African cassava mosaic disease (CMD) were studied in two split-plot experiments. Cassava canopy temperature, relative humidity, whitefly (*Bemesia tabaci*) population, and CMD incidence and severity were recorded bimonthly from 4 to 14 months after planting. Cassava canopy temperature significantly increased with wider spacing, but relative humidity was not affected by any treatment. The whitefly population and the incidence and severity of CMD increased with delayed planting and reached a peak for cassava planted in August. CMD incidence also increased with wider spacing and decreased significantly with increases in the number of cassava shoots per stand. The effects of the treatments on CMD are discussed.

The African cassava mosaic disease (CMD), first reported by Walburg in 1894 (Lozano and Booth 1976), occurs throughout East, West, and Central Africa and adjacent islands (Storey 1936; Storey and Nichols 1938; Chant 1959; Jennings 1960, 1970), causing decreases in cassava yield of 20–90% (Chant 1959; Jennings 1960; Doku 1965; Beck 1971; Bock and Guthrie 1978). Little is known about the epidemiology of the disease, particularly in relation to its control. In 1983, two experiments were initiated to determine the effects of cassava spacing, planting time, and the number of cassava shoots on whitefly population, CMD incidence, and CMD severity.

MATERIALS AND METHODS

The planting material used in the study was from a disease-free cassava stem (cv. Ebwanateraka). Both experiments were arranged in a split-plot design with four replicates.

In experiment I, planting times (main plots) were 8 April, 8 June, 8 August, 8 October, and 8 December 1983. The spacings of cassava (subplots) were 200 × 100, 75 × 75, 75 × 50, and 50 × 50 cm, with 100 × 100 cm, the current recommended spacing, serving as the control. These spacings were equivalent to plant densities of 5 000, 17 778, 26 667, 40 000, and 10 000 plants/ha, respectively. Each main plot was 28 × 5 m and was divided into five 4 × 5 m subplots; 2 and 3 m separated subplots and main plots, respectively.

In experiment II (spacing–shoot trial), four spacings (50 × 50, 50 × 75, 75 × 75, and 100 × 100 cm) were arranged in the main plots and three cassava shoot treatments (single [SS], double [DS], and multishoots [MS] per stand) were in the subplots. Each main plot was 18 × 5 m and was subdivided into three 6 × 5 m subplots; 2 and 3 m separated subplots and main plots, respectively. The trial was planted on 23 September 1983.

In both experiments, 30 cm long stem cuttings were planted horizontally in well-prepared flat seedbeds. Observations on the African mosaic disease were taken bimonthly from 4 to 14 months after planting. Disease incidence was noted as the percentage of plants infected, while severity was estimated from 20 randomly selected plants per plot, and estimated on a scale from 0 to 5: 0, no symptoms; 5, very severe mosaic symptoms.

The effects of treatment on plant canopy microclimate (under-canopy) temperature and relative humidity were evaluated while scoring for the disease. For statistical analysis, the average disease scores (incidence and severity) and relative humidities were arcsine transformed; temperatures were square-root transformed.

RESULTS

EXPERIMENT I

The whitefly population, CMD severity, and CMD incidence all increased with delayed planting, reaching maximum values in the August planting. Thereafter, however, all three parameters declined,

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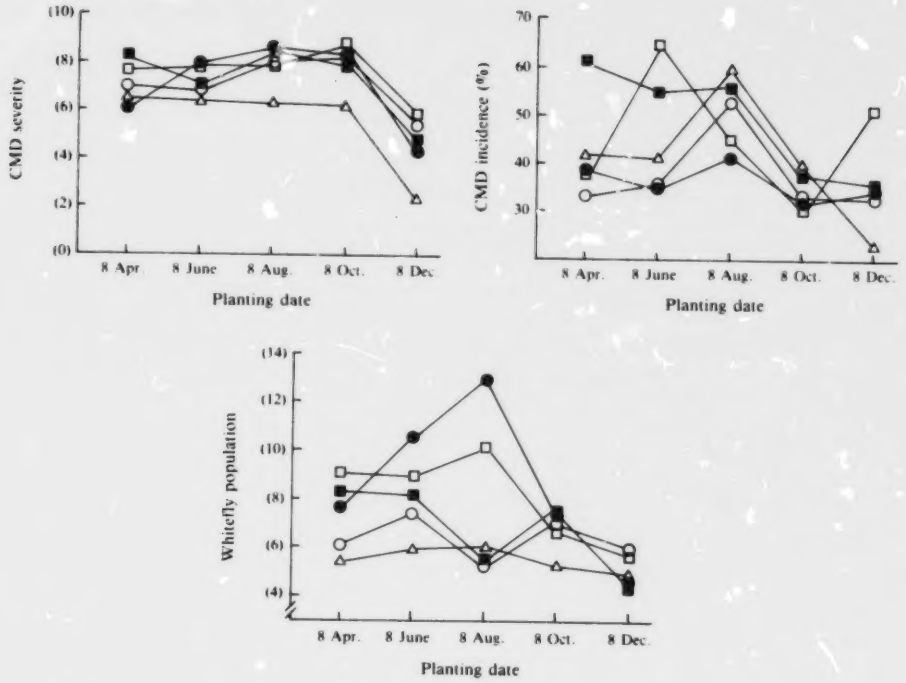

Fig. 1. *The effect of planting time and cassava density (plants/ha: △, 5 000; ○, 10 000; □, 17 778; ■, 26 667; ●, 40 000; for equivalent spacings, see text) on cassava mosaic disease (CMD) severity, CMD incidence, and whitefly population. Values in parentheses are arcsine transformed.*

reaching minimum values in the December planting (Fig. 1). Neither under-canopy relative humidity nor under-canopy temperature were affected by planting time (results not shown).

EXPERIMENT II

The whitefly population significantly decreased as plant density decreased (increased spacing), reaching a minimum at 10 000 plants/ha (100 × 100 cm). This response was negatively correlated with the effect of temperature ($r = -0.65$). Cassava canopy temperature increased significantly as plant density decreased. Maximum temperatures were reached at 10 000 plants/ha (100 × 100 cm spacing). Like canopy temperature, CMD incidence increased significantly as plant density decreased. Neither CMD severity nor cassava canopy relative humidity were affected by plant density (Fig. 2).

The number of shoots per plant seemed only to affect CMD incidence and whitefly population; CMD severity and cassava canopy microclimate appeared unaffected (Fig. 2). An increased number of shoots per plant reduced the whitefly population, although not significantly. CMD incidence decreased significantly as the number of shoots per plant increased. With respect to CMD incidence, there was a strong positive interaction between plant spacing and the number of shoots per plant.

DISCUSSION

Whiteflies multiply and develop faster under cool, less humid conditions. Hence, as plant density increases, lowering the cassava canopy temperature, the whitefly population also increases. This relationship also explains why whitefly populations were higher on cassava planted in August, a cooler, drier month. Later in the year, conditions are warmer and too dry to favour whitefly multiplication. Similarly, Bock and Guthrie (1978) observed that whitefly populations were high just before the rainy season and low for the rest of the year. Leuschner (1978), however, observed a lower CMD incidence and whitefly population in August. This may be due to different local ecological conditions.

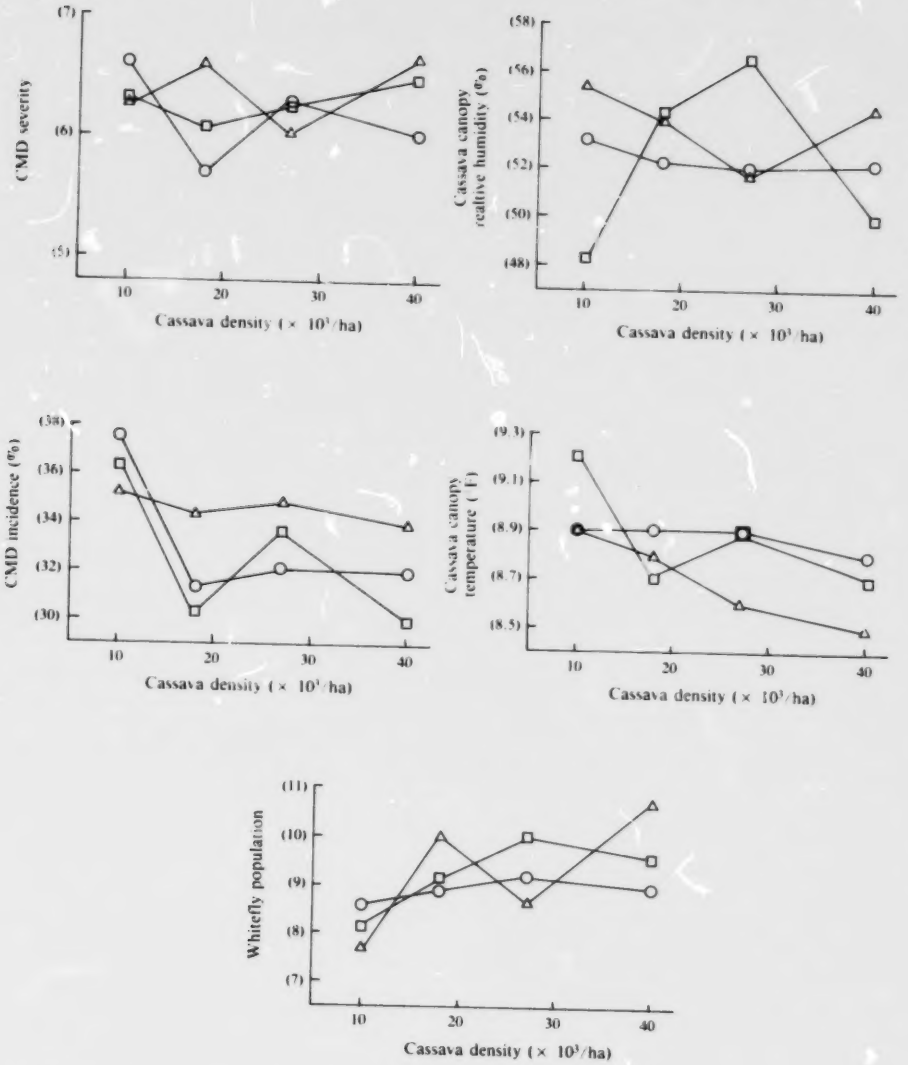

Fig. 2. *The effect of cassava density (for equivalent spacings, see text) and number of shoots per plant (△, single shoot; ○, double shoot; □, multiple shoots) on cassava mosaic disease (CMD) severity, CMD incidence, cassava canopy microclimate (relative humidity and temperature), and whitefly population. Values in parentheses are arcsine transformed, except temperature values, which are square-root transformed (t°F = [5 (t − 32)/9]°C).*

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STRATEGIES OF PROGRAMME NATIONAL MANIOC (PRONAM) OF ZAIRE IN SCREENING CASSAVA FOR RESISTANCE TO MAJOR DISEASES

A. MUIMBA-KANKOLONGO, G. MUYOLO, N.M. MAHUNGU, AND S.J. PANDEY[1]

The susceptibility of local cassava to disease is one of the most important factors that limit cassava yield in Zaire. Some of the most devastating diseases of cassava are bacterial blight, mosaic disease, and anthracnose. Resistance is certainly the most effective and widely used method for the control of these diseases. The various strategies and procedures of Programme national manioc (PRONAM) of Zaire in screening cassava for resistance to these major diseases are discussed. PRONAM has developed some good disease-resistant, high-yield varieties that are recommended to farmers for general cultivation.

In Zaire, cassava (*Manihot esculenta* Crantz) is the most important food crop and is grown on about 50% of the arable land. The tuberous roots of cassava are consumed mainly as chikwangue and fufu, meeting the energy needs of about 70% of the population. The leaves are eaten as a vegetable by low-income families and represent their most important source of protein and mineral salts. Unfortunately, in Zaire, cassava crops are affected by many diseases, the most devastating of which are bacterial blight, mosaic disease, and anthracnose.

Bacterial blight is caused by *Xanthomonas campestris* pathovar. *manihotis* and often results in considerable, sometimes total, losses in terms of tuber yield and the production of dry weight, leaves, and planting material (Lozano and Sequeira 1974; Obigbesan and Matuluko 1977; Terry 1977). The epidemic proportions of bacterial blight and the accompanying food shortages of the 1960s led to the development of Programme national manioc (PRONAM) of Zaire in 1974.

Cassava mosaic disease is endemic to all cassava-growing areas (Hahn 1979), where it reduces yield by 20–95% (Beck and Chant 1958). This disease is spread by whitefly (*Bemisia tabaci*) and through diseased cuttings.

Anthracnose is a nonsystemic disease that develops through the colonization by *Colletotrichum gloesosporioides* f.sp. *manihotis* of stem lesions produced by a sucking insect (*Pseudotheraptus devastans* Dist.) (Muimba 1982). This disease, which is severe when associated with bacterial blight (Muyolo 1984), affects the quality of the planting material and the germination of cuttings (CIAT 1977; Makimbila 1979).

PRONAM's objectives include the development of cassava varieties that are resistant to these diseases and produce high yields and by-products with acceptable organoleptic qualities. This paper discusses the strategies and methods used by PRONAM in obtaining resistant varieties.

RESISTANCE-SELECTION METHODS

Selecting for resistance to bacterial blight starts with collecting isolates of the pathogenic agent from various regions of the country. After testing for pathogenicity, the most virulent isolates are kept and regularly used in artificial inoculations. To this end, green sections of cassava plant stems are inoculated by injecting them with a suspension of bacterial cells using a syringe. The leaves are inoculated by infiltration using tongs holding a piece of sponge and rough-surface paper that have been previously soaked in the bacterial suspension (PRONAM 1978). The evaluation of clones is based on a rating scale from 1 to 5: 1, apparent field resistance; 5, interruption of the plant's apical growth followed by total dieback (PRONAM 1975).

Screening for resistance to cassava mosaic is carried out by removing the heads of the plants because harvesting the leaves has been found to facilitate the spread of this disease (PRONAM 1977, 1978). The evaluation of clones is based on a rating scale from 1 to 5: 1, apparent field resistance; 5, severe cassava mosaic with significant reduction of leaf surface (PRONAM 1975).

[1] Programme national manioc (PRONAM), Kinshasa, Zaire.

Table 1. New rating scale proposed for the evaluation of cassava anthracnose.

Severity category	Characteristic symptoms
0	No apparent symptoms in the plant
1	The green parts of the plant show the presence of necrotic lesions produced by the sting of sucking insects, but are not yet colonized; bending of the petioles at the point of insertion of the stem, and distortion of apical sections
2	Presence of oval-shaped superficial cankers on the green or lignified sections of the stem; the colour of the cankers varies from brown to blackish or whitish and is due to colonization by the anthracnose cryptogam
3	The green or lignified sections show the presence of numerous deep cankers that have been colonized or long superficial wet bands that have been colonized and are often accompanied by gum exudation; leaf necrosis and slight defoliation
4	Presence of colonized cankers in the form of fissures on the green or lignified sections of the plant; severe defoliation
5	Dieback

Source: PRONAM (1985).

Table 2. Reaction of the best PRONAM selections to the main cassava diseases.

Selection	Disease severity[a]		
	Cassava mosaic	Bacterial blight	Anthracnose
M'vuazi			
Kinuani	2.3	2.0	2.6
02864	2.7	2.0	3.5
30344/6/2	1.9	3.6	3.5
61665/4	1.7	2.4	2.0
50467/12	2.1	2.5	3.0
41784/9	2.0	3.0	3.0
40230/3	2.0	2.8	3.5
A 56[b]	2.6	4.5	2.8
cv. Mpelolongi[c]	2.3	4.0	3.5
Kiyaka			
F100	2.0	2.6	3.0
F150	2.7	3.0	3.0
F156	3.0	2.6	2.5
F113	2.6	4.0	3.0
F162	3.7	3.5	4.0
Gandajika			
5220-5217/7	1.9	3.5	3.0
A 56/1	3.6	3.5	2.5
GII/5	3.7	3.5	2.5
MWP/7	3.0	2.5	2.0
30085/28/10	3.0	2.5	2.0
30085/28/4	2.6	3.0	2.5
33787/6	2.9	3.0	2.0
Bitter cassava (6 months)	3.6	4.0	3.0
4(20426/1	2.8	2.5	3.0
60882/10	2.8	2.5	2.0
60441/8	3.9	3.5	2.5
30093/6	3.8	3.5	3.0
cv. Kazebe[c]	4.0	4.0	3.0

Source: PRONAM (1985).
[a]Rated from 1 to 5: 1, no symptoms; 5, severe infection.
[b]Source of the bacterial blight inoculum.
[c]Local cultivars.

As far as anthracnose is concerned, in view of the difficulties encountered in replicating characteristic symptoms by artificial field inoculation, our evaluation system is based on natural infection. This system was revised to adapt it to conditions in Zaire. In this new evaluation system (Table 1), the activity of *P. devastans* in the etiology of anthracnose and the effect of the combined bacterial blight–anthracnose infection on the severity of the symptoms are taken into account. In vitro selection tests are performed by inoculating sections of green stems that were previously pricked with a red-hot needle with pellets containing mycelial filaments of the causal agent. The results of these tests are then compared with observations on the aggressivity of the cankers in the field before the destruction of the clones (PRONAM 1985).

Only clones that scored from 1 to 3 in the bacterial blight and cassava mosaic rating scales and from 0 to 3 in the anthracnose scale were considered to be resistant and were retained for further evaluation.

RESISTANCE-SELECTION STRATEGIES

At present, selection for disease resistance in cassava is being actively pursued at three PRONAM stations: M'vuazi, Bas-Zaire; Kiyaka, Bandundu; and Gandajika, Kasai-Oriental. It is expected that the program will be expanded to include the equatorial forested regions, Haute-Zaire, and the mountainous regions of Kivu. In these three main stations, the process of selection starts in exotic and local seed nurseries (40 000–100 000 seeds). Local seeds are collected in isolated fields where local parent plants and selected exotic plants are grown on the basis of free pollination and controlled crossings (PRONAM 1975, 1977). The process of selection then continues in accordance with a schedule suitable to the needs of the program.

The seed nurseries and the samples used for clonal and preliminary yield tests are systematically inoculated with the causal agent of bacterial blight no later than 2 months after planting, during the heavy rain season in November or December (PRONAM 1978).

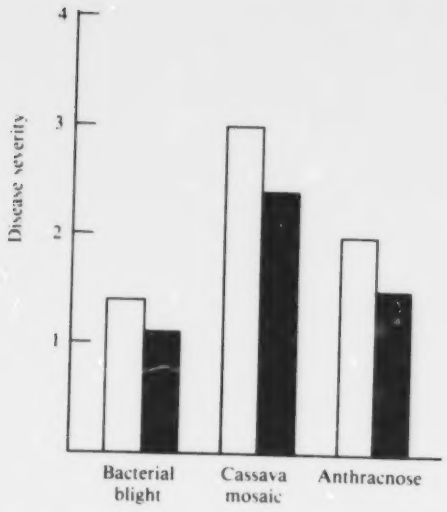

Fig. 1. *Reaction of the Kinuani variety (■) and local cultivars (□) to bacterial blight, cassava mosaic, and anthracnose in 88 demonstration fields in M'vuazi, Bas-Zaire, Zaire. Disease severity: 1, no symptoms; 5, severe infection.*

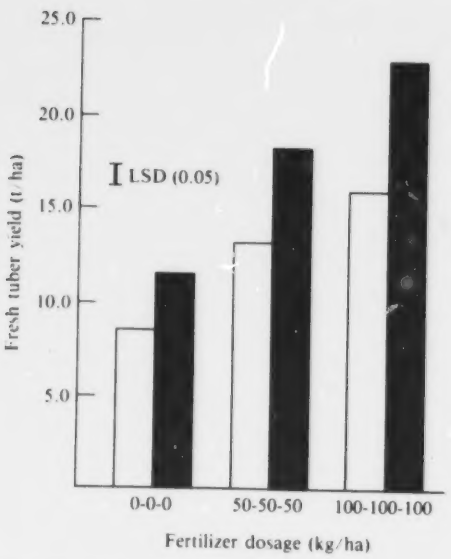

Fig. 2. *Fresh tuber yields of the Kinuani variety (■) and local cultivars (□) at three levels of fertilization (N–P_2O_5–K_2O) in 135 sites from 1981/82 to 1984/85 (M'vuazi, Bas-Zaire, Zaire). LSD, least significant difference.*

At the beginning of the dry season, 6 months later, when whitefly populations are high, the tops of the plants are removed (PRONAM 1978). The severity of bacterial blight and cassava mosaic is evaluated 2 months after the inoculation removal of the tops; anthracnose severity is evaluated about 6 months after planting, as soon as several cankers are observed on the stems.

Using uniform yield tests, the clones selected for multiple-location tests are reevaluated for resistance using artificial inoculation and removing the tops of plants in the experimental lots of the Phytopathology Section (PRONAM). Recommendations are then made to the person in charge of selection before large-scale multiplication and propagation of the successful clones is undertaken. At the level of the farmer, the demonstration and propagation fields are evaluated every year at the time when bacterial blight, cassava mosaic, and anthracnose are most likely to occur (May–June).

PRONAM ACHIEVEMENTS

The joint efforts of the Phytopathology, Selection and Improvement, and Multiplication and Vulgarization sections (PRONAM) have led to the identification of innumerable sources of resistance to the most important diseases. The selected parent plants, such as clones 30085/28, F100, 4(2)0426/1, 30572/149, 02864, 30010/10, 61665/4, 41784/9, 30344/6/2, etc., can be successfully used for artificial pollination and the production of local seeds.

Many tolerant varieties have been identified or developed (Table 2). Some of these, such as F100, Kinuani, and 4(2)0426/1, are already being heavily cultivated and distributed in Bandundu, Bas-Zaire, and Kasai-Oriental, respectively. Up to 1985, 300 000, 1 564 580, 000, and 41 650 m of planting material obtained from improved varieties had been distributed in Bandundu, Bas-Zaire, and Kasai-Oriental, respectively. This material can be used to plant about 120, 600, and 17 ha, respectively, on the basis of 2500 m planting material/ha.

The PRONAM varieties distributed to farmers behave and perform better than local materials in terms of both disease resistance (Fig. 1) and yield (Fig. 2). Kinuani and F100 varieties have average yields of about 9–15 and 13–20 t/ha, respectively, without fertilization. Under the same conditions, local varieties produce 3–12 t/ha.

CONCLUSIONS

To determine how long the developed disease resistance of our varieties will last, cultivars of the Kinuani variety were planted in a multivariety crop

Table 3. Reaction of the Kinuani variety to the main cassava diseases in mono- and multi-varietal crop systems.

	Disease severity[a]					
	Cassava mosaic		Bacterial blight		Anthracnose	
Planting systems[b]	3 months	6 months	3 months	6 months	3 months	6 months
var. Kinuani						
Alone	2.5	2.6	1.7	2.9	1.1	1.3
+ 30786	2.6	2.8	—	—	—	—
+ A56	—	—	1.8	2.8	—	—
+ 30757/5	—	—	—	—	1.2	1.4
+ 30786 + A56	2.5	2.7	1.7	2.8	—	—
+ 30786 + 30957/5	2.6	2.7	—	—	1.1	1.4
+ 30957/5 + A56	—	—	1.9	2.8	1.1	1.4
+ 30786 + A56 + 30957/5	2.7	2.7	1.6	2.8	1.3	1.4
30786[c]	2.9	3.4	—	—	—	—
A56[c]	—	—	2.1	3.7	—	—
30957/5[c]	—	—	—	—	1.8	2.7
LSD (5%)[d]	NS	0.2	0.3	0.1	0.3	0.2

Source: PRONAM (1985).
[a]Rated from 1 to 5: 1, no symptoms; 5, severe infection.
[b]30786 is susceptible to cassava mosaic; A56 is susceptible to bacterial blight; 30757/5 is susceptible to anthracnose.
[c]Average clone score for all treatments per repetition.
[d]LSD, least significant difference; NS, not significant.

system, similar to that used by the farmers, in combination with other sensitive varieties. The results show that the PRONAM variety has multiple resistance, at least in space, to the main cassava diseases encountered in Zaire (Fig. 1, Table 3).

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AN IN VITRO CASSAVA-INOCULATION METHOD FOR THE SELECTION OF ANTHRACNOSE-RESISTANT CULTIVARS

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The development of natural anthracnose lesions was compared with that of lesions artificially inoculated with *Colletotrichum gloeosporioides*. The in vitro inoculation method produced the same symptoms as the natural infections. This in vitro method provides a fast and easy way of selecting cassava cultivars resistant to *C. gloeosporioides* and of studying resistance mechanisms.

Cassava anthracnose disease is widespread throughout the world; however, it is generally considered to be of minor importance (Lozano and Booth 1974). Nevertheless, in some cases it can become an important limiting factor to cassava. In Zaire in 1975, 90% of the local cassava was severely attacked (Terry and Oyekan 1976).

No research studies have been able to establish a relationship between the severity of the disease and its effect on yield. Some researchers believe, however, that infected cuttings are less likely to strike and that the loss of many leaves and the necrosis of young shoots decrease the photosynthetic capacity of affected plants (CIAT 1977; Makambila 1979; Theberge 1985). This has stimulated interest in developing sufficiently resistant cultivars. Field tests carried out at the International Institute of Tropical Agriculture (IITA 1975) show differences between cultivars in the severity of attack. Most anthracnose lesions appear on the stems and branches after they are punctured by a Coreidae insect (*Pseudotheraptus devastans* Dist.). The role of this primary cassava pest was studied in Zaire by Dubois and Mostade (1973).

Even though the bite of *P. devestans* alone can cause defoliation in particularly sensitive varieties, its role in the etiology of anthracnose is to provide sites propitious to the establishment of colonies of the fungal parasite *Colletotrichum gloeosporioides* (Penz.) f.sp. *manihotis* Chev., as well as tissues that have been weakened by the lytic effect of the insect's saliva (Muimba 1982; Boher et al. 1983).

One of the main difficulties in evaluating cultivar resistance in the field is that the symptoms observed result from differences in how appetizing the cultivar is to the insect, the sensitivity of the cultivar to the insect bite and the toxic saliva, the sensitivity of the cultivar to *C. gloeosporioides*, and the distribution of the inoculum and infection conditions. The selection of cultivars using an artificial inoculation method and stem cuttings provides a singular method to evaluate sensitivity to the pathogenic agent.

This type of in vitro inoculation method has already been used at IITA by Lamé (1982), Ahouandjinou (1983), and Goffart (1984) in studies on the selection of cultivars for their resistance to anthracnose and the characterization of *C. gloeosporioides* strains isolated from cassava. A serious limitation in these tests, however, was the development of secondary infections that prevented more precise observations of the host–parasite relationships. Within the framework of a collaborative study carried out jointly by the Université Catholique de Louvain, Louvain-la-Neuve, Belgium, and IITA, Ibadan, Nigeria, the stem cutting inoculation method was optimized to develop a fast selection method for cultivars resistant to *C. gloeosporioides* and to study resistance mechanisms. Our goal was to standardize what happens in the field under optimally controlled but easily obtained conditions. For this reason, the development of anthracnose lesions resulting from natural infections was monitored in the field in Nigeria, and tissue alterations were compared with those observed after in vitro inoculation.

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EQUIPMENT AND METHODS

DEVELOPMENT OF NATURAL ANTHRACNOSE LESIONS

To understand the development of the various symptoms, over 500 lesions were recorded in the field in July 1985 and changes in the lesions were monitored for 1 month. The observations were made at IITA, Ibadan, in a field of growing, 1-year-old cassava (cv. 30572). Lesions were rated from 1 to 4: 1, lesions as a result of an insect bite but not infected by *C. gloeosporioides;* 2, active anthracnose lesion; 3, anthracnose canker, the epidermis is light brown and frequently injured, and colonization by the fungus is interrupted by a layer of lignified cells; 4, necrosis of the tops.

ARTIFICIAL IN VITRO INOCULATION METHOD

Stem pieces (chunks measuring ca 7.5 cm) were obtained from the most sensitive part of the stem located between 15 and 45 cm from the top. The greater sensitivity of this area has been observed both at IITA (Ahouandjinou 1983) and in Belgium by in vitro microcutting of 2-month-old plants.

The surface of the stem pieces was disinfected by soaking for 1 min in 2% sodium hypochlorite. After rinsing, the pieces were incubated in a moist chamber at 26°C with a photoperiod of 12 h light – 12 h dark and an illumination of 8000 lx. Each piece was incubated in an individual 5-mL flask to prevent secondary infection. To stimulate the damage resulting from the bite of *P. devastans*, a fine needle was attached to a needle holder leaving a protruding length of 1 mm and heated between each inoculation. The stem was pricked with the red-hot needle three times in 3 s, in three locations forming an equilateral triangle with sides measuring 1.5 mm. This type of injury was used by Makambila (1982) and Muimba (1982) on whole plants.

The inoculum (a pellet measuring 6 mm in diameter and obtained from the edges of a *C. gloeosporioides* culture that had been grown for 7 days on an oat medium) was placed on the injury. Cultivars 30211, 30337, and 30555 were selected at IITA, and cultivar M.ECU 82 was supplied by Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. Strain 2009 was isolated at Ibadan, Nigeria; strains Mw and G were isolated from plant material obtained from Zaire.

Table 1. Virulence of *Colletotrichum gloeosporioides* isolates on cassava cv. 30555 with 10 repetitions at 4, 10, and 21 days after inoculation.

	4 days		10 days		21 days
Isolate[a]	IF[b]	Canker size (mm, $\bar{X}\pm$SD)	IF	Canker size (mm, $\bar{X}\pm$SD)	IF
2009					
NI	10	8.1±1.4a	7	8.4±1.2	2
I	0		3	55.2±20.1	8
NW1					
NI	10	8.5±1.7a	7	8.9±1.9	6
I	0		3	60.0±17.3	4
NW2					
NI	10	8.8±1.9a	8	9.8±3.2	4
I	0		2	50.0±14.1	6
NW3					
NI	10	7.8±1.4ab	10	8.6±1.9	10
I	0		0		0
G1					
NI	10	8.5±1.1a	10	10.6±2.2	8
I	0		0		2
G2					
NI	10	6.6±0.86	10	8.1±2.0	7
I	0		0		3
G3					
NI	10	7.7±1.2a	9	9.3±5.0	7
I	0		1	25.0±0.0	3

Note: Mean values followed by the same letter are not significantly different by the LSD test.
[a]I, invaded (invasion of the stem with acervuli appearing outside the brown necrosis; epiderm macerated); NI, not invaded.
[b]IF, invasion frequency.

Table 2. Resistance of cassava cultivars to infection by *Colletotrichum gloeosporioides* isolate 2009 (20 cuttings per cultivar) at various times after inoculation.

Cultivar[a]	4 days	5 days	7 days		9 days	10 days	
	Canker size (mm, $\bar{X}\pm$SD)	IF[b]	IF	Canker size (mm, $\bar{X}\pm$SD)	IF	IF	Canker size (mm, $\bar{X}\pm$SD)
M.ECU82							
NI	9.6±1.1a		1	10.1±0.0		1	10.1±0.0
I		13	19	55.9±18.2	19	19	70.0±0.0
30337							
NI	9.6±1.3a		11	10.4±2.2		5	9.8±2.3
I		7	9	35.6±9.9	11	15	55.1±22.4
30211							
NI	8.4±1.5b		16	10.3±2.6		13	10.8±2.8
I		1	4	25.8±5.4	4	7	63.1±18.1
30555							
NI	7.8±0.9b		13	9.1±2.8		11	9.9±2.9
I		4	7	44.0±18.1	7	9	61.0±17.9

Note: Mean values followed by the same letter are not significantly different by the Newman–Keuls test.

[a]I, invasion of cutting occurred (arcevuli appeared outside brown necrosis; epiderm "macerated"); NI, colonization remained restricted to the brown anthracnose lesion at the inoculation point.

[b]IF, invasion frequency.

Results and Discussion

The Symptoms and their Development

Pseudotheraptus devastans injuries produced oval-shaped, darker green wet areas measuring about 1 cm in diameter, often with a healthy-looking spot in the centre. This injury either caused the collapse of young stems without secondary support structures or, when the epidermis cells became dry, it developed into a light-brown, oval-shaped spot, a symptom that is erroneously considered to be the first sign of anthracnose (*C. gloeosporioides* has rarely been isolated from this type of lesion). After 1 month, 43% of the lesions caused by the insect bite were not colonized by *C. gloeosporioides* (lesion rating 1).

The colonization of tissues weakened by the toxic saliva of *P. devastans* produced dark brown lesions (rating 2). The fructification of the fungus appeared as small agglomerations of pink conidia. The outline of most lesions infected by *C. gloeosporioides* remained clear, and these lesions changed into more or less deep cankers where the epidermis was severely injured and light brown in colour.

After 1 month, the number of active lesions (rating 2), had dropped from 70 to 3%. These lesions mostly developed into clearly outlined cankers (lesion rating 3). Colonization by the fungus was interrupted and the infected tissues were surrounded by a layer of lignified cells. Under unfavourable conditions (which remain to be defined), these active lesions expanded before a complete lignified barrier could form: 14 of 100 branches became entirely colonized by the fungus (lesion rating 4).

At first sight, the symptoms of necrosis in the tops, which is caused by *C. gloeosporioides*, were similar to the symptoms observed during an attack of bacterial blight, and they are often confused. The study of the development of natural anthracnose lesions confirms these observations and makes it possible to produce a global image of the various types of lesions.

Development of an Artificial In Vitro Inoculation Method

The development of lesions artificially inoculated with *C. gloeosporioides* was the same as that of natural lesions. An analysis of the colony by aseptic sampling and microscopic observation revealed that the epidermis cells reacted to the mycelium penetration attempts by necrotizing the invaded cells, browning the walls of neighbouring cells, and forming lignified papillae. These mechanisms effectively controlled infection through the undamaged epidermis. However, the mycelium formed extensive colonies in tissues injured by the needle and produced symptoms that were similar to those observed in the field during natural infection. About 12–24 h after inoculation, a browning was seen around the edges of the lesion and was localized mainly along the cell walls. The brown spots then advanced and formed a continuous brown area that moved with the attacking front of the mycelium. After the 4th day, lignification began ahead of the colonization front. When this lignification formed a continuous barrier to the mycelium, its advance was stopped. Mycelium may cross the barrier and colonize the entire stem piece. This invasion is marked by faster fungal

growth, a significant production of conidia, and an attenuation of the dark brown edges of the lesion; the tissues in the centre of the lesion lose consistency and appear soft and wet.

A comparison of strain 2009 of *C. gloeosporioides* isolated in Ibadan, Nigeria, and isolates from Zaire and Brazil confirmed the strong virulence of strain 2009 (Table 1). Strain 2009 was also the most virulent of the 22 strains isolated in Nigeria and tested by Goffart (1984). Thus, on the basis of the virulence of the inoculum present, Ibadan appears to be an adequate location for the selection of resistant cultivars. The inoculation of various cultivars allows differentiation between them in terms of their sensitivity to the pathogen. A comparison of sensitive and resistant cultivars evaluated during this initial test and the results obtained at IITA (Ahouandjinou 1983) led to cultivars 30211 and 30337 being selected by IITA as reference cultivars (Table 2). Cultivar 30211 is more resistant than cultivar 30337 and this difference is especially marked in terms of the number of stem fragments invaded by the fungus.

The factor that best differentiates between the resistance levels of the cultivars seems to be their resistance to "invasion" (corresponding to the symptoms of necrosis in the tops as a result of natural infections). This may be used as a selection criterion for resistance to anthracnose introduced by in vitro inoculation.

This method of artificial inoculation has made it possible to study host–parasite relationships in more depth, and demonstrate the plant's disease-resistance reactions. This study was mainly concerned with phenol metabolic changes (common resistance reaction in many plants [Friend 1981]) and, in particular, with changes in peroxidasic activity, tissue lignification, and the appearance of compounds toxic to fungi. This study has confirmed similarities in plant reactions following in vitro inoculation and natural infection in the field (unpublished results).

CONCLUSIONS

An artificial inoculation method was developed that made it possible to produce the same symptoms as natural infections; anthracnose lesions developed either toward cankers defined by a layer of lignified cells that isolated the tissues colonized by the pathogen, or toward an invasion of the stem (necrosis of the top that is similar to the symptoms of bacterial wilt). This inoculation method allows the virulence of *C. gloeosporioides* isolates from various countries and continents as well as the sensitivity of various cassava cultivars to be compared. It has been used as a test of selection for anthracnose resistance.

The infection causes various plant reactions that tend to control the infection. Nevertheless, under unfavourable conditions (which remain to be defined), some stems are colonized by the fungus and this leads to symptoms of necrosis of the tops.

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ABSTRACTS

EVALUATION OF CHEMICAL SEEDBEDS AND PREEMERGENCE HERBICIDES FOR WEED CONTROL IN SWEET POTATO – MAIZE INTERCROPS

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Experiments in humid, central southeastern Nigeria during 1983 and 1985 evaluated the delayed seeding technique, involving paraquat (0.5 and 0.75 kg active ingredient [ai]/ha) applied at 14 and 28 days after land preparation and before seeding or glyphosate (2.0 kg ai/ha) applied at 28 days after land preparation and 2 days before seeding, preemergent application of chloramben (3.4 kg ai/ha), fluometuron (2.5 kg ai/ha), and alachlor (2.0 kg ai/ha), and manual hoeing at either 21 days or 21 and 56 days after planting. Unweeded and weed-free treatments were included to estimate the herbicide and weed interference effects on crop yield, and unweeded and weed-free sole components estimated the effect of intercropping on the yields of the individual maize and sweet potato components. Intercropping sweet potato with maize depressed yields of maize grain and fresh sweet potato tubers by 2-year averages of 30 and 33%, respectively, compared with the sole maize (2.8 t/ha) and sole sweet potato (3.6 t/ha). However, by intercropping, the farmer would obtain the same yield as growing maize and sweet potato individually and still have a 2-year average of 25% of the farmland available for other purposes (land equivalent ratio = 1.33). Uncontrolled weeds caused a 45% reduction in the maize component compared with the weed-free maize yield (2.0 t/ha). Similarly, uncontrolled weeds reduced the sweet potato component by 57% compared with the weed-free yield (2.3 t/ha). In monetary terms, the current practice of hand-hoeing at 21 and 56 days after planting yielded a 2-year average of NGN 2795 (in February 1987, 2.6 Nigerian naira [NGN] = 1 United States dollar [USD]). Preemergent application of chloramben and chemical seedbeds involving paraquat (0.75 kg ai/ha) or glyphosate (2.0 kg ai/ha), applied 28 days after land preparation and before seeding, gave 2-year average monetary yields of NGN 2740, NGN 2527, and NGN 2532, respectively.

EFFECT OF PLANTING TIME ON CASSAVA YIELD AND THE POPULATIONS OF CASSAVA MEALYBUG (*PHENACOCCUS MANIHOTI*) AND ASSOCIATED PARASITOIDS

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The effect of planting time on the populations of cassava mealybug (*Phenacoccus manihoti*) and associated parasitoids was studied in relation to the cassava yield. Yield differences were significant ($P \geq 0.05$) between early and late planting. Plots planted early (March to mid-July) had well-established plants and lower populations of *P. manihoti*. Root and stem yields decreased with increasing populations of *P. manihoti*. The parasitoids *Epidinocarsis lopezi* and *Tetrastichus* sp. showed a density-dependent relationship with *P. manihoti*. Two hyperparasites, *Prochiloneurus insolitus* and *Chartocerus* sp., were identified as factors that decrease the effectiveness of *P. manihoti* parasitoids.

RESISTANCE OF CASSAVA CULTIVARS TO GREEN SPIDER MITE (*MONONYCHELLUS TANAJOA*) INFESTATION

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Twenty-one cassava cultivars selected after field screening for tolerance to *Mononychellus tanajoa* (Bondar) (green spider mite) were artificially infested with *M. tanajoa* in the greenhouse to confirm their resistance. Of 21 selected cultivars, the mean mite damage scores showed TMS 4(2)1425 to be the most tolerant to *M. tanajoa* infestation, followed by 74/538, Anti-Ota, 73/93, 30195, and 1531. These cultivars supported fewer mites and four of them, TMS 4(2)1425, 73/93, 74/538, and Anti-Ota, had surface hairs on their leaves — an attribute of resistance. Mite damage and mite density were not correlated with variations in leaf HCN content. This factor, therefore, does not contribute to mite resistance in cassava.

CHEMICAL CONTROL OF FOLIAR DISEASES IN ROOT AND TUBER CROPS

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Foliar pathogens of yam, cassava, cocoyam, sweet potato, and Irish potato cause dieback, spots, wilting, branch and leaf proliferations, distortion, leaf stunting, and stem tissue necrosis. The following pathogens are common: *Fusarium oxysporum*, *Fusarium solani*, *Collatotrichum gloeosporioides*, *Curvularia eragrostidis*, *Cercospora vicosa*, *Sclerotium rolfsii*, *Botryodiplodia theobroma*, *Xanthomonas manihotis*, *Cercosporidium henningsi*, *Colletotrichum* spp., *Albugo impomocae pandusatal*, *Phaevisariopsis bataticola*, *Pseudoceraspora timorensis*, *Phyllosticta batatas*, *Septoria bataticola*, *Phytophlhora infestans*, and *Pseudomruas solanacearum*. Because of the morphology and growth patterns of these pathogens, chemical control is uneconomical. Cultural practices, the use of resistant varieties, and improved sanitation are the recommended disease-control methods.

RESISTANCE OF HYBRID MACABO (*XANTHOSOMA SAGITTIFOLIUM*) TO ROOT ROT CAUSED BY *PYTHIUM MYRIOTYLUM* IN CAMEROON

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Root rot caused by *Pythium myriotylum* Drechsl is a limiting factor on macabo (*Xanthosoma sagittifolium*) yield in Cameroon. Tests on the resistance of hybrid clones are promising and research is being carried out along these lines. The clones studied showed an improved tolerance to root rot. The presence of a large number of healthy roots will lead to an increase in the number of secondary tubers and yield.

EFFECT OF PARASITIC DISEASES ON THE PRODUCTION OF POTATOES (*SOLANUM TUBEROSUM*) IN CAMEROON

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In Cameroon, potatoes are produced mainly in the high regions of the west and northwest. In 1979/80, production (mainly in small farms) amounted to 25 000 t. Potatoes are intercropped with other plant species (corn, beans, peanuts, macabo/taro, etc.). At present, two crops per year are grown. Parasitic diseases (virus diseases, alternariose, mildew, verticilliosis, and bacterial wilt) are one of the main factors limiting the productivity of potatoes in the high western plateau. The relative importance of these diseases is described. At present, the Institut de la recherche agronomique (IRA), within the framework of the National Root Crops Improvement Program (CNRCIP), is attempting to obtain high-yield potato cultivars that are resistant to the most damaging diseases. It has been estimated that tuber storage losses (essentially related to rot) are more than 25%. *Fusarium solani* and *Fusarium coeruleum* are responsible for a high percentage of this rot.

NEW PRIORITIES IN CASSAVA SELECTION IN ZAIRE

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Since 1974 and the creation of Programme national manioc (PRONAM), cassava-selection procedures have been reactivated in Zaire. The principal objectives of the program are the production of high-yield tubers that are resistant to diseases and pests. At present, apart from these initial selection criteria, particular attention is being given to the quality of the roots in terms of HCN content, dry weight, and the organoleptic qualities of products consumed as vegetables. Photosynthetic effectiveness of leaves at low sun exposures, morphologies suitable for intercropping, and the speed of growth of the clone at a young age have also been considered selection criteria in the present program. The methodology used to evaluate these various criteria is discussed.

INTERACTIONS BETWEEN *PSEUDOTHERAPUS DEVASTANS*, *COLLETOTRICHUM MANIHOTIS*, TEMPERATURE, AND RELATIVE HUMIDITY IN THE DEVELOPMENT OF ANTHRACNOSIS IN CASSAVA

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Interactions between *Pseudotherapus devastans*, *Colletotrichum manihotis*, temperature and relative humidity were studied in the development of cassava anthracnosis. Young manioc plants were infected with *C. manihotis* by placing conidae of the fungus on artificially (needle or scalpel) or naturally (*P. devastans*) induced wounds. After inoculation, stem fragments were kept at high (85–90%) and low (50–60%) humidities. The effect of temperature on fungus development was evaluated by incubating the inoculated stem fragments at 12, 16, 20, 24, 28, 32, and 36°C. The results show that natural wounding by *P. devastans* is essential to the development of the disease. In the absence of such a wound, the fungus does not produce infectious hyphae. High humidity (85–90%) is necessary for anthracnosis symptoms to appear; low humidity (50–60%) inhibits fungal propagation. The optimum temperature range for appressoria differentiation is 20–28°C; the disease flourishes from 24 to 28°C.

POSTHARVEST TECHNOLOGY

POSTHARVEST TECHNOLOGIES OF ROOT AND TUBER CROPS IN AFRICA: EVALUATION AND RECOMMENDED IMPROVEMENTS

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Food self-sufficiency in Africa depends on increased production, reduced postharvest losses, improved processing methods, and improved product distribution. This paper summarizes the main causes and extent of root and tuber postharvest losses, evaluates the major postharvest technologies, and recommends a project to increase the availability of root crop products, based on an integration of production and postharvest activities. Yams and cassava are emphasized.

Midway to the deadline established by the Lagos Action Plan to reach food production self-sufficiency in Africa, the chances that supply will match demand in the food sector are rather hypothetical: agricultural production is increasing by less than 2% per year and the population is growing by about 3% per year. With one of the most inadequate crop-production techniques, characterized by the use of inferior means and production factors, Africa does not produce enough food to feed its population. Thus, postharvest techniques used to prevent and reduce losses, process agricultural products, facilitate their distribution, and increase their availability are particularly important.

Self-sufficiency in food production cannot be achieved simply by increasing production and preventing and reducing postharvest losses, adequate processing and better distribution conditions also play an important role. Roots and tubers occupy a position of prestige among the staple foods of Africa. In the intertropical humid regions of Africa, from Gambia to Tanzania through Angola and Zambia, yams, cassava, sweet potatoes, and cocoyams are mainstays in the diets of millions of people. These products, which represent the main source of carbohydrates for the populations of these regions, however, have poor keeping qualities and are very susceptible to losses; therefore, in spite of relatively high production rates, roots and tubers fail to play a decisive role in meeting the food requirements of Africa.

In spite of their great diversity, existing postharvest techniques used to process roots and tubers do not seem to have a significant impact on improving the availability of these foods. Many studies have been carried out on the techniques used to process roots and tubers. This study summarizes the main causes and extent of root and tuber postharvest losses, evaluates the major postharvest technologies, and recommends a project to increase the availability of these products based on an integration of production and postharvest activities. We emphasize cassava and yams, which are by far the most important root and tuber crops both in terms of quantity and their place as a staple in the diet.

CAUSES AND EXTENT OF ROOT AND TUBER LOSSES

REASONS FOR LOSSES

Losses appear at all stages from the field to the consumer's table. There are losses during harvest, transportation from the field to the farm or storage facilities, storage, transportation to the markets, and processing. At all these stages, losses are caused by various factors. They may be due to external agents (insects and other predators) or physical factors (handling, transportation, and storage conditions), or they may have physiological origins (Table 1).

At each potential loss stage, in relation to the nature of the various causes and agents, it is necessary to use specific loss-prevention and control technologies. To be effective, postharvest technologies must, as much as possible, take into account both the exogenous and physiological factors that may cause losses.

Losses caused by physiological factors are more difficult to control and are specific to the product. In fact, in the case of the two most important tropical

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Table 1. Stages and reasons for root and tuber losses.

Stage	Reason for loss
During harvest in the field	Infestation by insects in the field before or during the course of maturation
Transportation from the field to the storage facility	Inadequate transportation or inadequate packaging (causing injuries)
Storage	Inappropriate storage structures that allow infestation by worms and insects (especially in the case of yams), attack by predators, and development or continuation of physiological activities (germination, respiration, etc.)
Distribution	Inadequate packaging (causing injuries)
Processing	Inferior processing technologies causing both qualitative and quantitative losses

root and tuber crops, cassava and yams, the losses related to the physiology of the products are due to different causes.

In yams, losses are due to three phenomena. First, there is weight loss caused mainly by tuber dessication and respiration after dormancy. Coursey and Russell (1969) have shown that very substantial weight losses are due to respiration. With healthy tubers, respiratory activity accounts for 30% of the weight loss. Second, losses may be due to variations in the chemical composition of the tubers. This mainly affects the glucide content and seems to occur after the opening of the buds, when there is a mobilization of reserves for synthesis of the shoots. Third, losses result because of hardening, which makes the tuber difficult to chew and is not eliminated by cooking. This phenomenon affects mainly *Dioscorea dumetorum* and prevents any possibility of storage and marketing beyond the production area because it appears only a few days after harvesting. Among the causes of hardening, the degree of maturation at the time of harvesting plays an important role.

In cassava, the causes of deterioration unrelated to external physical causes have been studied within the framework of a joint program of the Tropical Products Institute and Centro Internacional de Agricultura Tropical (CIAT). It has been clearly established that cassava deterioration takes place in two phases: first, primary deterioration characterized by vascular discolouration or streaking and solely because of physiological causes; and, second, secondary deterioration characterized by the invasion of the root by specific varieties of bacteria or fungi.

Apart from these losses of mainly physiological origin, it is important to describe those caused by fungi, bacteria, and nematodes, which often appear in the field and continue during the course of storage. Insect and rodent attacks both on fresh and processed products also contribute to crop losses.

Evaluation of Losses

Roots and tubers are considered to be highly perishable foods. In Africa, loss levels around 20% are common. Under certain conditions, however, losses may reach 30 or 40%. According to these 1983 Food and Agriculture Organization (FAO) production values, losses for cassava and yams amounted to 14 000 t with a value of almost USD 2×10^6. This represents an enormous loss for Africa, where food production is already inadequate.

Storage Technologies

Storage technologies are mainly concerned with limiting the deterioration of the products while keeping them fresh as long as possible and retaining their nutritional properties. Some existing root and tuber storage techniques have been used more or less successfully in Africa.

Yams

In the case of yams, it is mainly a question of preventing sprouting, which is the physiological phenomenon responsible for weight loss and variations in chemical composition (Treche 1980). The simplest techniques are based on better storage conditions where the tubers are kept in an enclosed, well-ventilated environment, preferably in single layers. The most striking results have been obtained using a technique that consists of spearing individual tubers on stakes. In variation of this method, the tubers are arranged on shelves especially made for this purpose. These techniques are simple and effective, but require a significant amount of labour, and this tends to limit their adoption in certain regions where the agricultural schedule does not allow available workers to become involved in such tasks.

Another simple technique involves exposing the tubers to the sun for a few hours before storage. In fact, Booth (1974) demonstrated that exposing tubers to high temperatures and relatively low humidity made it possible to extend their shelf life. This method is used traditionally and empirically in West Africa.

Other techniques include low-temperature storage (10–20°C) and the use of hormones that prevent sprouting, which, according to yam studies carried out by Thompson et al. (1977) and Passam (1977, 1982), have produced good results. Knowledge of these techniques is not widespread, however, and they are practically never used in Africa because of their high costs. This is also the case with irradiation techniques, which, in spite of their effectiveness, are not widely used in Africa for financial reasons and because they require specialized labour. Nevertheless, this technology could play a major role in reducing general agricultural losses in Africa if it could be introduced into a properly structured, well-implemented regional project.

CASSAVA

The storage problems of cassava are different. Cassava roots are different from yams in that they are not dormant organs and thus have very few biological functions. The most reliable storage technique for cassava roots involves providing moisture to the product. This can be done by wrapping the roots in a moist, absorbent material in the ground, in silos or mills, and, for transportation, in various types of containers. These techniques are widely used in Africa, where they make it possible to keep cassava fresh for more than 6 weeks (under normal conditions, deterioration starts 3–7 days after harvesting).

Some studies have shown that there are close relationships between physiological deterioration and mechanical damage, and between injury and product dessication. Storage methods based on controlling dessication by storing fresh cassava in plastic bags have produced good results. Many regions of Africa still employ the traditional storage method, and harvest cassava only as needed. Apart from the fact that this technique produces soil disturbances that could lead to serious soil availability and utilization problems, after some time, the buried cassava becomes lignified and its starch content decreases.

PROCESSING TECHNOLOGIES

The purpose of processing is to control the deterioration of the food products. It is of great importance both as a means and as an end: it is used to prevent losses and it represents the final stage in the production of food for the people. Processing is even more important when we consider that other preservation techniques have certain limitations.

In general, processing technologies can be classified into three categories: traditional, cottage industry, and industrial technologies. We will evaluate each of these categories on the basis of the following factors:

- their utilization restrictions;
- their acceptability in the socioeconomic environment of the consumer;
- their impact on loss reduction; and
- the quality of the final products.

CASSAVA

Apart from controlling losses, postharvest processing decreases the toxicity of cassava by reducing its cyanogenic glucoside content. In areas where large amounts of cassava are consumed, studies have established the presence of high rates of neurological disorders related to the presence of hydrocyanic acid, e.g., optical atrophy, bilateral deafness, and myelopathy.

Processing techniques are based on several operations, of which the most important are peeling, soaking (which eliminates toxic substances through the use of hydrolyzing enzymes), drying, and cooking (which eliminates hydrocyanic acid). The main products obtained from these various processing operations are flour and cassava rolls (chikwangue) in Central Africa and gari in West Africa. Cassava chips, which represent a temporary way to keep the product, are used to produce flour (Fig. 1).

TRADITIONAL TECHNOLOGIES

PRODUCTION OF CASSAVA ROLLS — There are four distinct steps involved in the production of cassava rolls: peeling, soaking, grinding, and wrapping.

Peeling: The cassava root has two skins, an exterior fine film that can be easily removed and a thick, whitish, internal peel, or phelloderm, that tends to cling more or less closely to the flesh. Even though it is nutritionally richer than the pulp, the phelloderm is not used because of its high cyanogenic glucoside content. Traditionally, cassava is peeled by hand using a knife or machete. This is a laborious operation and yields about 200 kg cassava/day.

Soaking: To eliminate cyanide toxicity and soften the roots to facilitate shredding and grinding, cassava is soaked in water for 3–6 days.

Grinding: A stationary grindstone consisting of a heavy flat stone and a roller made of a cylindrical stone weighing 2–3 kg is used. Grinding is exhausting work and yield is generally low, depending upon the amount of waste (fibres that have not been softened by soaking) contained in the root.

Wrapping: After grinding, the paste is shaped into rolls and wrapped in leaves (tropical creeper), tied, and either boiled or braised. In this form, cassava can be easily transported without damage and kept for several days or even weeks.

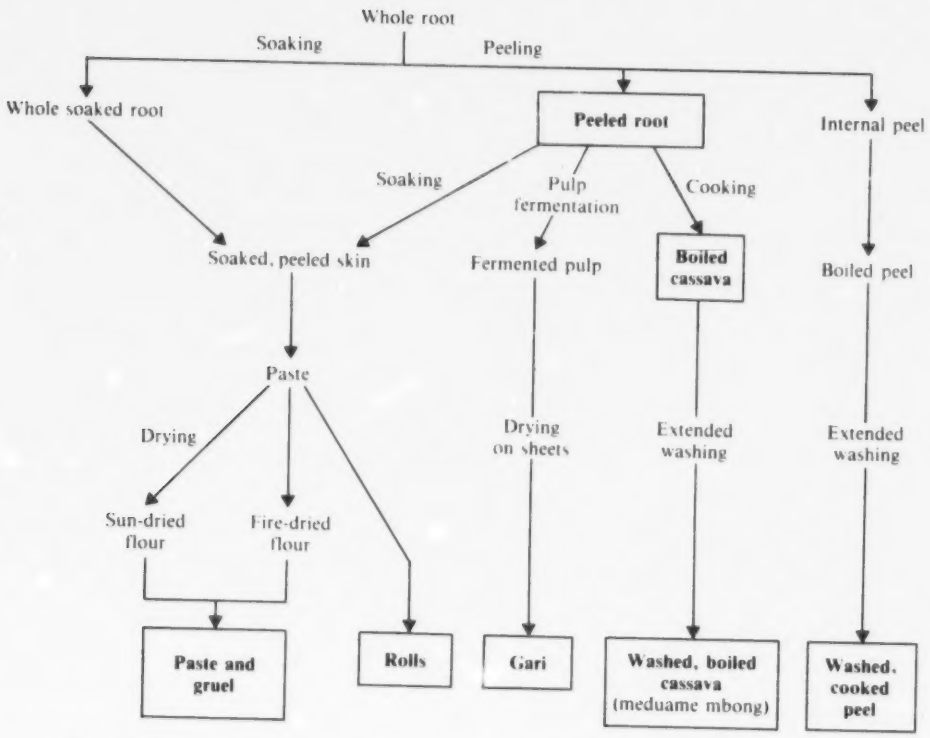

Fig. 1. *Traditional methods of processing cassava root; directly edible products are shown in boxes.*

PREPARATION OF GARI — There are seven steps involved in the preparation of gari: peeling, grating, pressing, crumbling–screening, garification, and screening.

Peeling: The technology is the same as that used to make cassava rolls. The peelings to whole root ratio is 1:4 (Table 2).

Grating: In the traditional process, the peeled roots (pulp) are grated using a perforated metal sheet attached to wooden supports. This operation requires skill and concentration. Severe finger injuries are frequent among the workers. In this operation, the hourly yield per worker is around 20 kg.

Pressing: The moist pulp, containing 65% water, is pressed in bags that are then weighted down. When the quantity to be processed allows, many bags are piled on top of each other; this facilitates pressing. Pressing lasts for 3 or 4 days, during which time the pulp ferments; proper fermentation requires around 30 days.

Crumbling–screening: The pressed pulp, which forms a compact mass, must be crumbled and screened. This operation, used to eliminate fibres and large particles, is carried out using a traditional screen made of woven fibres. The moist pulp is constantly stirred by hand. In this operation, the daily yield per worker is about 100 kg starch.

Table 2 Changes in weight and moisture content during gari preparation

Product	Weight (kg)	Dry weight (kg)	Moisture (%)
Whole fresh roots	100	53	65
Pulp	75	29	62
Pressed pulp	53	27	50
Starch	50	25	50
Unfinished gari	28	25	10
Finished gari	27	24	10

Garification: In this operation, the pulp is roasted and dried, producing unfinished gari (Table 2). The product gelatinizes, giving gari its particular characteristics. Garification is carried out in gourd halves or large bowls made of fired clay and placed over a wood fire. This is an arduous operation because of the discomfort suffered by the operator, who is exposed to the heat and the steam produced by the hot

wet pulp. Thus, one person can produce only around 50 kg gari/day.

Screening: Screening the unfinished gari is easier than screening the moist pulp and is carried out with a screen made of woven fibres, which, in this case, has a finer mesh. Screening is used to refine the granularity of the finished product.

CASSAVA CHIPS AND FLOUR — After peeling, the cassava is washed, cut into small chunks, and allowed to dry in the sun on wire nets, cement floors, or bare ground. The product takes 4 days to dry in the dry season and 8 days to dry in the rainy season. The conditions of traditional drying methods are slow and unsanitary, which means the final product is often invaded by moulds that produce a greenish colour. In some regions, the chips are also dried over wood fires. The dry chips can be stored for a long time and are ground only as needed. The flour is made by pounding using a mortar and pestle or by grinding using a grindstone. It has been found that 12 kg of dry chips can be ground by one person in 20 min. The flour is used for the preparation of pastes and fufu. In Central Africa, cassava flour is also made from a dry paste made from steeped cassava. Properly dried chips are a very good way to store cassava.

COTTAGE INDUSTRY TECHNOLOGIES

Many research and development studies have been undertaken with various amounts of success to improve the work of women in the various separate operations involved in processing cassava. These improvements have been essentially concerned with the most arduous and laborious operations, such as peeling, grating, or grinding the dry chips. Despite the drudgery involved in the methods used to screen the fresh paste and prepare the gari, they have not been fundamentally modified.

PEELING — Mechanical peeling techniques (abrasion) have been studied and tested; however, at present, and probably over the short term, it does not seem possible to mechanize this operation in any effective or economic way at the cottage industry level. At the present state of development, mechanical peeling produces higher losses (33%; manual method, 25%) and requires a significant amount of additional manual labour.

GRATING — Improvement efforts have focused mainly on this operation. This has resulted in the introduction into the African market of grating machines consisting of a motor and a grater–screen unit. The motors are always imported; however, the grater–screen is almost always manufactured locally. Although these mechanical graters introduce a new step in the manufacturing process, they free women from a very arduous task, allowing them to process larger amounts; this has a significant effect on reducing losses.

GRINDING THE CHIPS — In the traditional system, grinding is exclusively a manual task using a mortar and pestle or grindstones. At present, however, it is carried out mechanically in areas where hammer crushers have been introduced.

SCREENING THE MOIST PASTE — The compact and wet nature of the paste after pressing does not facilitate screening. Experimental equipment has been developed in certain institutions (e.g., University of Nsukka, Nigeria); however, it has not yet been possible to master all the conditions that would allow the popularization of these techniques (large-scale testing, profit-making capacity in comparison with more traditional methods, etc.).

GARIFICATION — Without question, this is the most arduous operation in the cassava-processing system after grating. In spite of the existence of equipment such as metal garification ovens equipped with chimneys and mechanical stirring systems, garification is still carried out in the traditional way by many gari producers, even when they have adopted improved technologies for the other operations. This seems to be due to the specificity of this operation, which combines gelatinization and cooking of the cassava particles. The homemaker has a certain empirical mastery of this operation; however, this does not necessarily ensure that the improved technology will be used skillfully. The quality of the finished product and, thus, its acceptance by consumers, who have fixed habits, is greatly dependent upon the quality of garification. Thus, it is easy to understand any unwillingness to adopt proposed technological improvements. Apart from these purely technical aspects of garification, there is also the problem of the consumption of energy needed for cooking. Improved furnaces, which save fuel and allow the women to work away from fire and smoke, have been introduced in some areas. This type of equipment should be further developed.

INDUSTRIAL TECHNOLOGIES

In Africa, the cassava-processing industry, which produces edible flours that are used in the preparation of traditional foods, in combination with other flours, and in planning or manufacturing staples such as gari and cassava rolls, has developed at a very moderate pace. Apart from starch factories, cassava-processing plants "look like an odd assortment of patchwork equipment." This has led to equipment incompatibility and inconsistent processing lines and, consequently, has produced rather discouraging results at both the technical and economic levels. In the cassava-processing industrial sector, a lot of research and development is still needed to improve existing techniques and equipment. In general, technological improvements in the industrial system have been mainly concerned with mechanizing the

separate operations used in the traditional and cottage industry methods to carry them out on a larger scale. In most cases, these improvements lower the quality of the finished products; this often results in a disappointing market performance of the manufactured products.

The most interesting industrialization attempts in this sector have been carried out in the Congo for the manufacture of cassava flour, in Côte d'Ivoire for flour and attieke, in Gabon for cassava processing, and in Nigeria for the production of gari. It is interesting to note that, in these plants, some operations that represent bottlenecks in the traditional and improved technologies have been solved more or less satisfactorily:

- In a flour-manufacturing plant in Mantcoumba, Congo, the Bertin Company of France has participated in the development of a mechanical peeling machine that can process 700 kg/h. The system has to be stopped manually, however.
- In its plant in Toumodi, Côte d'Ivoire, the I2T Company has developed a continuous mechanical peeling technique that includes a phase to remove the outer peel or skin of the root; a laminating and separating phase during which the pulp, but not the phelloderm or the root fibres, is ground (the components of the pulverized pulp are then separated by rolling); and a refining phase that makes it possible to obtain a ground pulp that is free of fibres. Thus, this single operation combines root peeling and grating.
- In Nigeria, in a plant operated by the Federal Institute of Industrial Research of Oshodi (FIIRO), there is a continuous garification process. Once the paste has been pressed and crumbled, it is put into a cooker equipped with paddles, where it is directly cooked by the heat produced by an oil burner. After cooking, the pellets are put in a rotating dryer where they are dried by a flow of hot air to a moisture content of 12%.

Mechanization of the process used to manufacture gari and cassava flour and rolls, with good profit-making conditions in the production units (while retaining those qualities of the finished product that are desired by the consumer), requires the use of large quantities of raw materials. The finished products are stable and keep well; this will have a significant impact on reducing postharvest losses.

Yams

In Africa, in spite of their importance as a food staple, yams are almost exclusively processed by traditional methods. In general, yams are cut into chunks and boiled or ground using a mortar and pestle to obtain a glutinous paste (fufu) that is eaten with sauces (Fig. 2). This product is only processed to obtain dry yam chips and flour made from these chips. These processed products keep well.

Research on the manufacture of instant yam flour has show that, when reconstituted, this product does not have the characteristics and qualities of the flour obtained from chips. During the production of instant yam flour the cells do not disintegrate and release the starch. This results in a product without the characteristic gelatinous consistency of fufu. Research is continuing in this area. The industrial process to obtain yam flakes is similar to that used to make instant flour but is not commonly used in Africa.

Effect of Cassava-Processing Operations on Product Quality

Peeling can eliminate over 50% of undigestible glucides while retaining over 80% of the food energy (calories); however, there are also losses of proteins, calcium, vitamins (thiamine and riboflavin), total minerals, and ascorbic acid (Table 3). Eliminating the peel is beneficial from the point of view of toxicity, because its cyanogenic glucoside concentration may be 2.6 times higher than that of the flesh in bitter cassava varieties and up to 10 times higher in sweet varieties.

Soaking eliminates toxicity and results in a significant decrease in the content of hydrocyanic acid. The effects of steeping are not solely beneficial, however, because, with the elimination of cyanogenic glucosides, there is a concomitant decrease in nutritional elements through dissolution (Table 3). It has been found, however, that the fermentation produced during long steeping facilitates riboflavin synthesis.

Even though the preparation of cassava rolls makes it possible to recover about 55% of the dry weight, glucides, and calories, and over 60% of the riboflavin present in the whole root, it nevertheless causes the loss of other nutrients, particularly vitamin C, which may be completely eliminated. During the course of gari preparation, grating decreases the vitamin C content (62% in the peeled root, 51% in the pulp) and, during the pressing–fermentation process, the pressing drains away between 21 and 28% of the mineral salts as well as significant proportions of thiamine and ascorbic acid (29 and 75%, respectively). During garification, more than half of the ascorbic acid remaining in the fermented pulp is lost, and 20 and 13% of vitamins B and B_1, respectively, are also lost.

It is evident that processing improves storage characteristics, which is important in the case of

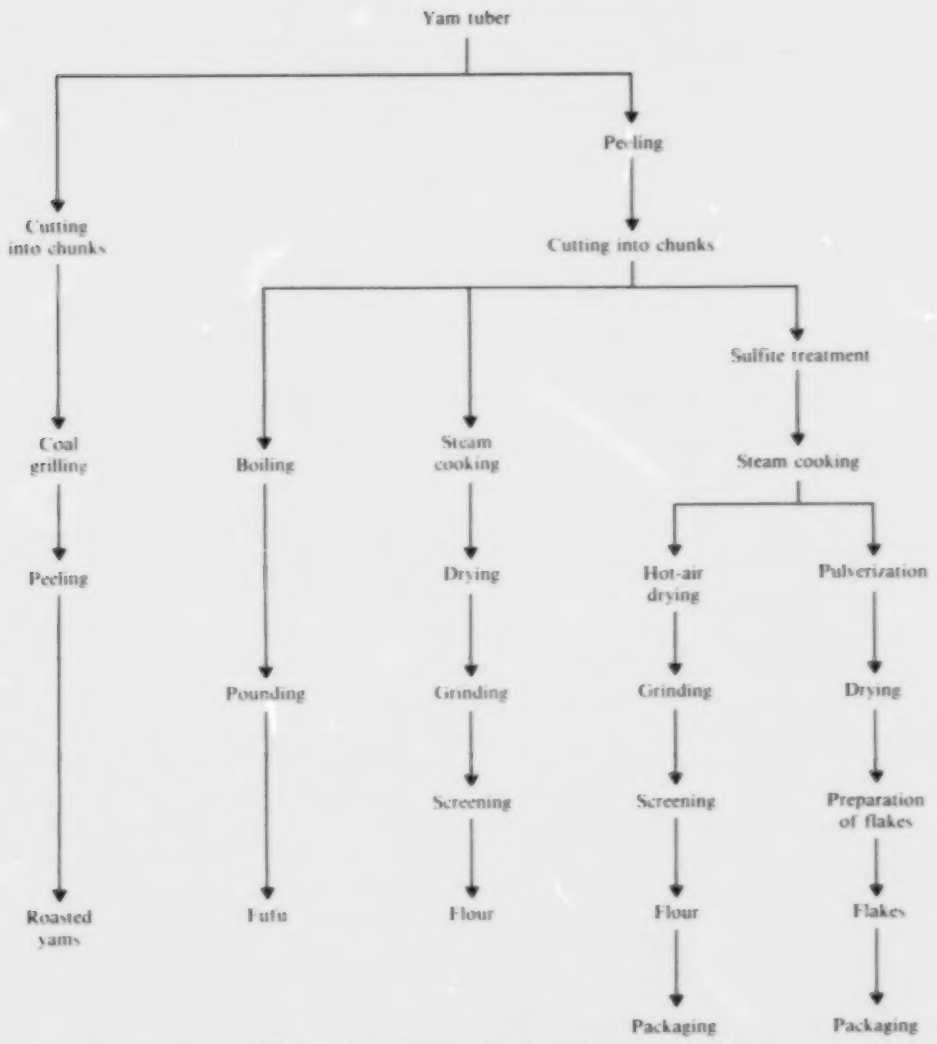

Fig. 2. *Traditional methods involved in yam processing.*

highly perishable foods like cassava, but that, taking into account the various nutritional losses (Table 3), the processed products have an essentially low nutritional value and that this has a deleterious effect on the people's diet.

SOCIOECONOMIC ASPECTS

As in the case of other foodstuffs, traditional cassava processing is a female activity. Taking into account that the roots are available throughout the year and that, to control losses, harvesting is staggered in time and the crop is harvested only as needed, processing does not have a particularly seasonal character. Although processing is a family activity (involving women and children), in some cases, the crop is processed on a cooperative basis by two or several families, especially in the case of operations that represent bottlenecks, such as peeling, manual grating, and garification.

Table 3. Effect of various preparation phases on the nutritional value of cassava.

	Peeling	Soaking without peel (peeled root)	Soaking with peel (peeled root)	Pressing fermentation (pulp)	Garification (pulp)
Dry weight	−12	−7	−8	−1	−5
Food energy (calories)	−19	−6	−7	−1	−4
Protein	−53	−45	−11	−17	−6
Fat	−17	−12	−18	−36	—
Total glucides	−18	−6	−7	—	−5
Indigestible glucides	−54	−20	−26	−3	−4[a]
Ash	−87	−47	−25	−21	−11
Calcium	−48	−31	−11	−21	−3
Total phosphorous	−17	−48	−18	−21	−3
Plant phosphate	−17	−71	−38	−28	−1
Iron	−86	−12	−1	—	+124
Niacin	−29	−54	−25	−34	−3
Vitamin B_1	−57	−41	−24	−29	−20
Vitamin B_2	−47	−50	−66	−6	−13
Vitamin C	−38	−76	−75	−75	−54

Note: Values represent the percentage loss or gain with respect to the original basic product.
Source: Favier (1980).
[a]A value of +194 was obtained, but this was mainly due to the oil coating of the cooking bowl.

The introduction of improved technologies upsets this social organization to the extent that it brings the men (who alone operate the machines) into the processing work. In some regions, the development of improved technologies is accompanied by the organization of cooperative structures to facilitate the purchase of equipment and ensure their profit-making capacity. This is because the cost of the equipment is often beyond the investment possibilities of the farmers (Table 4) and the size of the family farm sets a limit on the amount of raw materials available. The use of cottage-industry technologies in a rural environment presents other significant problems, such as the need for skilled labour to operate and maintain the equipment, and the energy required to operate the machines (Table 4). Electricity and other conventional energy sources are rare in rural areas, and it is important to have research and development efforts oriented toward the development of technologies that do not require skilled labour and are able to use new and renewable energy sources.

In collaboration with the Food Research Institute (FRI) of Ghana, the African Regional Centre for Technology, Dakar, Senegal, has launched a project to establish a cassava-processing plant that meets these requirements. The project is concerned not only with developing tools and materials suitable for a rural environment, but also with taking into account the technical problems of processing itself as well as the problems related to energy needs. The use of by-products obtained from peeling and grating to produce the energy required for processing forms an integral part of this project.

It seems clear that it is a reduction in the cost of these improved technologies, especially in their operating costs once they are implemented, that will determine the popularity and profit-making capacity of these plants. This does not seem to be the case with cottage-industry and industrial technologies that presently exist in the cassava-processing sector.

Conclusions

Although traditional techniques give products that meet the organoleptic quality demands of the consumers, they are limited in terms of their utilization conditions, their low yield, the sanitary quality of their products, the rather inadequate contribution that they make toward reducing losses, and the small quantities that they can handle. Industrial technologies would have a clearly positive impact on reducing losses if their adoption was not limited by serious socioeconomic handicaps. Taking into account the level of industrial development of African countries and their level of production (small, moderately unproductive family farms and wide geographical distribution), it seems that, at present, postharvest technologies used at the cottage-industry level are the most suitable and effective solution to the problems involved in processing roots and tubers in a rural environment. The proper introduction of cottage-industry technologies based on improved traditional technologies would allow roots and tubers to play a greater role in achieving self-sufficiency in food production in Africa.

Table 4. Economic data of various types of cassava processing.

	Traditional technologies	Semimechanized technologies	Cottage industry technologies	Industrial technologies
Capacity (t/day)	1	2	4	15[a]
Production of gari (t)	0.20	0.44	1.00	3.75
Performance (%)	20	22	25	25
Initial investment (XOF × 10⁶)[b]				
Building	0.5	0.5		
Equipment	0.05	0.3	10	250
Labour (people)	12–15	30	16	11[c]
Energy consumption				
Firewood (XOF)	1600	3600		
Fuel (L/t cassava)		20	36	34
Costs of gari (XOF/kg)				
Fixed	22.5	23	11.5–15.6	23–28
Variable	88	87	72.7	72.2

Source: BEFTA (1982).
[a] Eight-hour working day.
[b] In March 1987, 309 CFA francs BCEAO (Banque Centrale des Etats de l'Afrique de l'Ouest) (XOF) = 1 United States dollar (USD).
[c] Number of people per team.

Many research and development institutions are working at the national and regional levels either to increase the productivity and yield of roots and tuber crops or to improve the processing technologies. In terms of production problems, important results have been obtained by institutions such as CIAT and the International Institute of Tropical Agriculture (IITA). They are developing new high-yield varieties that are more resistant to diseases and other pests, and better adapted to the ecological conditions of the region. Along with these new varieties, more suitable processing technologies must be developed, from new harvesting methods to the processing of roots and tubers to produce edible finished products. Unfortunately, studies on production are often not coordinated with those carried out on postharvest processing. A global approach in the form of regional projects with the participation of both national and regional institutions should be envisaged. These institutions would cooperate in searching for viable solutions. The general objectives of this project would be the coordination of the two aspects of research and development related to the production and processing of roots and tubers and a better coordination of efforts in the two sectors to prevent useless duplications and allow a maximum utilization of resources to obtain definite results within the shortest possible time.

RECOMMENDATIONS

OBJECTIVES

An integrated project for the improvement of production, quality, and postharvest technologies should combine, in a regional network, national, subregional, and regional African institutions working in the root and tuber production and processing sector. Other competent institutions outside Africa could become associated with this project, which would be carried out over a period of about 5 years. The project would have seven specific objectives:

- To develop a research program to improve yield, sprouting resistance, storage properties that improve resistance to insect attacks, the characteristics of the finished products, and the suitability of the crop to mechanical harvesting and processing techniques.
- To develop methods to produce appropriate propagation materials using tissue cultures, plastid cultures, and other new methods.
- To develop research and development activities to improve traditional technologies and techniques that could be used to process tubers to reduce postharvest losses and facilitate the marketing and distribution of the crops.
- To design and develop a small-scale, cassava-processing system, especially for the peeling, grating, screening, and cooking operations.
- To promote the development of local skills for the production of viable technologies for processing roots and tubers.
- To review ongoing studies and conduct research on the parameters that affect the keeping quality of roots and tubers, and to disseminate knowledge and the results of research studies on questions of storage: e.g., the effects of ventilation, diffuse lighting, protection, hormone treatments, and the use of irradiation techniques.
- To develop and distribute information relative to the development and improvement of root and tuber processing methods.

JUSTIFICATION

Roots make up 31% of the food staples produced in sub-Saharan Africa and represent the main source of food energy for more than 300 million people in the continent. The leaves of edible root plants (cassava) are a preferred vegetable and provide protein, vitamins, and mineral salts. From a biological point of view, roots contain more food energy than any other food, especially in tropical areas. Roots and tubers not only produce a high level of edible carbohydrates but also have a high protein content. Cassava leaves have a raw protein content that varies between 26 and 41%, and sweet potato leaves have a protein content of 13–28% calculated on a dry-weight basis.

In spite of these clear advantages, the emphasis placed on research and development of root crops has not been proportional to their importance as food crops and, increasingly, as industrial and animal feed crops. Moreover, all other aspects of various research and development projects, such as attempts to increase production, improve quality, or develop new processing technologies, have not formed part of an integrated attempt to deal with biological constraints, the lack of planting materials, and storage problems, which demand closer attention.

BIOLOGICAL CONSTRAINTS

Significant progress has been made within the framework of joint programs carried out by national institutions and IITA for the production of high-yield cassava varieties with high levels of resistance to cassava bacterial blight (CBB) and cassava mosaic disease (CMD). These varieties are also resistant to attacks by insects such as the aleurodid or cassava mealybug (CMB) and the cassava green mite (CGM). At the same time, promising varieties of yams, sweet potatoes, and taro have been developed. These promising varieties have been tested and adapted for growth in some countries; however, it is necessary to pursue and intensify this type of effort.

The main selection criteria used have been high yield and resistance to diseases and pests. A few studies have been designed to choose varieties suitable for mechanical planting and harvesting, mechanical processing, and long-term storage. It will be necessary to undertake research and development work to produce varieties with characteristics such as uniformity in the size and shape of the tubers (to facilitate mechanized harvesting and processing), low cyanide content, better chemical composition for processing, better storage qualities, less likelihood of rotting, sprouting control (for yams), low postharvest losses, and the possibility of fast multiplication.

PLANTING MATERIALS

To improve the production levels of roots and tubers, appropriate techniques to ensure the fast multiplication and distribution of healthy planting materials must be developed. It is easy to understand the importance of this type of work, when we consider that one-fifth of the production of yams is used to plant the next crop. About 3 t of planting materials are required for each hectare of cassava under cultivation, and the rural producer does not have the financial means to purchase these materials.

In collaboration with national research institutes in Africa, IITA has developed a technique for the fast multiplication of cassava and yams. The technique used with yams is called "seed yam production technique" and uses mineral fertilizers and plastic mulches. Other research and development studies should be undertaken to improve this seed yam production technique to decrease production costs.

TESTING NETWORK

Existing techniques (improved varieties and fast multiplication) should be tested and evaluated in various countries. The same is true for new techniques that will be developed within the framework of this project and adopted after testing by various countries. In this respect, it is necessary to launch pilot projects in five countries representative of the various ecological areas in Africa. After this pilot test, appropriate planting materials would then be distributed to various national institutes for reproduction.

POSTHARVEST TECHNOLOGIES

Development strategies in Africa attach great importance to the improvement of traditional technologies within the framework of improving the quality of life in rural areas, where most of the population lives and works. This strategy is based on the principle that, in Africa, development does not make sense unless it is organized around the rural areas. Moreover, this strategy is based on the need to reach a certain equilibrium in the development of rural and urban areas to decrease the exodus to the cities.

This attempt to develop rural areas generally leads to an integrated development of resources, ensuring the growth of agricultural and food production and the creation of small-scale agricultural industries. Traditional technologies represent a good starting point to provide the understanding required for the reconstruction of an autonomous industrial infrastructure in the rural areas.

The traditional methods used to process roots are generally difficult and are carried out by women. An improvement of these methods would make it

possible not only to decrease the effort required by the traditional method but also to increase the incomes earned by women. Thus, an important objective of the program is to emphasize the need to improve the traditional systems to meet national needs in terms of food production by promoting the production and consumption of basic foodstuffs. A joint program would allow all the technological resources of the region to be examined in the interest of all participants.

Storage

Decomposition caused by fungi, bacteria, and nematodes starts in the field and continues during the course of storage. It causes enormous losses during storage. Germination of yam tubers and insect and rodent attacks also tend to increase losses during storage. Between 30 and 40% of the whole crop may be lost during storage. The reproduction of varieties with better keeping qualities represent one way to reduce losses; however, research and development activities are necessary to determine the various biological, physical, and ecological parameters that affect storage, and to design better yam storage conditions. Sophisticated techniques to prevent yam germination, such as irradiation, could be studied.

Expected Results

Improvement of Roots and Tubers

The project should improve the quality of root and tuber crops in four ways. First, high-yielding varieties that meet certain conditions and specifications for the growth and processing of crops in the various production areas could be identified and popularized. Second, pilot test and experimentation sites using newly developed varieties would be set up. Third, a network made up of national institutions for the production of propagation materials would be established. Fourth, experimentation parameters for extending the shelf life of roots and tubers using hormone treatments and irradiation techniques could be identified.

Postharvest Technologies

Improved and more suitable technologies based on the traditional techniques used to process roots and tubers have been developed, and studies to adapt these for use with suitable equipment have been carried out. Research and development programs concerned with new food-processing techniques, such as direct drying soon after harvesting the cassava crop, have been implemented. Pilot and demonstration plants suitable for various root crops using viable techniques that could be adapted for use with small processing plants at the rural level have been installed.

Evaluation studies would be conducted in various countries having different production and processing conditions in their root crop regions. These evaluations would describe processing methods and raw materials, identify the difficulties encountered, and identify problems and needs to reduce losses and solve technological problems related to the use of traditional methods. Users and workers coming from the informal and small metallurgical sectors on-site would be trained in pilot and demonstration units to teach them to operate farms and to maintain, repair, and copy equipment to support local manufacturing and management skills in the plants. Study visits to demonstration facilities for managers and entrepreneurs would be arranged to facilitate the marketing of newly developed techniques. Films with soundtracks in local languages and other audiovisual materials to support diffusion and training activities would be produced and distributed.

Activities to be Undertaken

Improvement of Roots and Tubers

In relation to root and tuber crop improvement, ongoing research and development projects in various regional institutions must be examined and the results obtained must be evaluated. Programs to develop new varieties with certain defined characteristics and parameters must be set up. Pilot experimental sites (five) to test new varieties must be established. Research on fast propagation and multiplication methods and to define the parameters required for a long shelf life must be initiated. Experimentation with irradiation and other techniques must also be initiated.

Postharvest Technologies

In relation to the postharvest technology of root and tuber crops, there are nine activities that must be initiated. First, results must be evaluated to identify any pertinent knowledge that could be diffused and the areas that should be emphasized on the basis of available skills. Second, identified needs must be used as the basis for developing cooperative research and development programs to help national, subregional, and regional institutions. Third, laboratory and pilot tests must be implemented for the development of new cassava-processing methods using solar energy and biomass. Fourth, pilot and demonstration units (five) must be established using viable root and tuber processing techniques on the basis of traditional methods, improved techniques, and new methods. Fifth, training courses at the demonstration

sites for private sector and small business operators must be organized to develop local processing means and duplicate processing plants. Sixth, study visits by managers and business operators to demonstration facilities must be organized. Seventh, pilot and demonstration units must be evaluated. Eighth, audiovisual material for the diffusion of promising technologies must be produced. Ninth, and lastly, organizational diagrams of the techniques learned for further diffusion must also be produced.

Measures to be Implemented

Improvement of Roots and Tubers

The means required to ensure the implementation of this part of the project should include the following measures:

- Temporary personnel or people under short-term contracts (consultants, temporary assistants).
- Analysis of existing documents, and selection and dissemination of the best varieties developed during the course of research and development studies (acquisition of documents, analysis by the consultants and institutional personnel, distribution of reports and publications throughout the country).
- Cooperative research for the development of new seed varieties with specific parameters (laboratory materials, additional equipment, analyses, and reports).
- Cooperative studies on the physical parameters that affect root and tuber storage (materials for laboratory and pilot tests, analyses, and reports).
- Laboratory studies on the use of irradiation techniques to extend shelf life (supply of materials to institutions that have the necessary equipment, experimental tests, and reports).
- Management and coordination of institutional networks used to carry out cooperative studies and management of experimental tests in the field (meetings at the network level, and supervision and coordination of activities at the focal points of the network).
- Choosing sites for pilot tests to be carried out on available varieties and those developed on the basis of research and development activities and testing storage structures and arrangements (seeds and other materials, additional equipment, additional personnel, cost and transportation, and site maintenance).
- Project follow-up and evaluation.
- Reports on activities and final reports, publications, and dissemination of results.

Postharvest Technologies

To cover the cost of implementing this part of the project, the following factors are required:

- Temporary personnel with short-term contracts (consultants, temporary support personnel).
- Study of traditional technologies and analyses of factors and needs (development of survey methods, identification of sites and national institutions that would be in charge of carrying out fieldwork, collection of data, cost of collecting the data, analysis of data collected, report on the results obtained, and coordination).
- Cooperative research to reevaluate traditional technologies and introduce new technologies (materials, additional equipment, laboratory tests, and technicians).
- Cooperative research and development work on new processing techniques (collection and supply of raw materials, materials required for the implementation of new techniques, and laboratory and pilot tests on new equipment).
- Management of coordination activities and technical committees.
- Implementation of five pilot and demonstration units using suitable technologies (tools and equipment for the plants, support personnel for the construction, transportation costs, and operation and maintenance of the sites).
- Field training in the demonstration sites, study visits, exchange programs, and bursaries (travelling and per diem costs for the participants, and training materials).
- Project follow-up and evaluation.
- Production of audiovisual and support material and diagrams illustrating the technologies for purposes of diffusion (films with soundtracks in local languages, slides, and drawings).

To cover these costs, the assistance of foreign funding organizations must be obtained. Other costs, such as offices, laboratories, research installations, and workshops; researchers (among personnel in place who will participate in the project); fields for on-site testing and experimentation activities; transportation equipment; and personnel for the organization and execution of field tests and the organization of field surveys and evaluation of the reports should be provided by the African institutions involved in the project.

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TRADITIONAL POSTHARVEST TECHNOLOGIES OF ROOT AND TUBER CROPS IN CAMEROON: STATUS AND PROSPECTS FOR IMPROVEMENT

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Root and tuber crops are important staple foods in Cameroon. The 1981/82 output was 1.9×10^6 t compared with about 0.8×10^6 t for cereals. Existing traditional handling and processing methods are inadequate and result in enormous postharvest losses. To outline priority research areas in root crop postharvest technology, a survey of existing root crop handling and processing techniques was undertaken. We found the cultivation of cassava, cocoyams, yams, and sweet potatoes to be widespread in all regions of the country; however, large-scale commercial production or processing units were rare. Farm holdings are generally small and harvesting patterns range from single harvest to harvest as needed. Elaborate storage structures are lacking. Relative to cereals, root crop losses to pests are minimal; the greater proportion of postharvest losses are due to poor handling, physiological factors, and pathological factors. Only cassava is traditionally transformed into numerous products; the other root crops are generally consumed as basic vegetables. The young leaves of cassava, cocoyams, and sometimes sweet potatoes are used as human food, but only sweet potato vines and tubers are fed to animals. This survey indicated that postharvest technology research on root crops in Cameroon should emphasize the development of simple efficient storage techniques, the improvement of existing handling and processing methods with special regard to hygiene and quality standards, the development of industrial products from tubers, the formulation of new competitive fast foods, the development of animal feeds, and the collection of more scientific data on root crops with respect to varieties and environmental factors.

Important tropical root and tuber crops in Cameroon include cassava (*Manihot esculenta* Crantz), cocoyams (*Xanthosoma sagittifolium* and *Colocasia esculenta*), yams (*Dioscorea* spp.), and sweet potatoes (*Ipomoea batatas*). The other root and tuber crops either have been recently introduced or are of limited, local importance. This survey concerns root and tuber crops as staple foods; thus, those of medicinal or pharmacological importance are excluded.

Total output of the major root and tuber crops in Cameroon during the 1981/82 season was estimated at 1.9×10^6 t, compared with 0.8×10^6 t for cereals (sorghum, millet, maize, and rice) over this same period (Table 1). Compared with cash crops and cereals, there has been little research on root and tuber crops. Recently, however, research has been initiated to improve production. Knowledge of postharvest technologies, however, remains tenuous.

Coursey (1967) estimated postharvest losses of tropical root crops to be 25% of production. Based on this modest estimate, postharvest losses of root crops in Cameroon for the 1981/82 season would amount to 0.5×10^6 t. This estimate involves losses in the quantity or quality of the produce caused by physical, physiological, and pathological factors. Losses occur at various postharvest stages: harvesting, gathering, transportation, storage, processing, culinary preparation, and consumption.

Traditional African societies have evolved simple technologies for reducing postharvest losses. Because of rapid population growth and shortened handling and preparation times, however, these apparently ingenious methods are inadequate for current needs. Consequently, consumers prefer foreign-processed foods.

Available research results on postharvest technologies of root crops in Cameroon (IRAT 1967; Favier et al. 1971; Platon 1971; Favier 1977) are crop specific and do not comprehensively assess traditional postharvest technologies. To fill this gap, we surveyed existing traditional methods of processing and preservation. Our goal was to formulate future research priorities in the postharvest technology of root and tuber crops in Cameroon.

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Table 1. Production ($t \times 10^3$) of root and tuber crops and total cereals in Cameroon during the 1981/82 season.

Crop	Province							
	Extreme North, North, and Adamawa	Northwest	West	Southwest	Littoral	Centre and South	East	Total
Cassava	51	64	86	64	80	194	100	638
Cocoyam	20	160	227	115	67	167	62	819
Yam	14	78	107	50	39	110	3	402
Sweet potato	8	20	30	1	4	4	0.5	68
Total root crops	93	322	451	230	190	475	166	1927
Total cereals	401	127	164	15	30	29	19	786

Source: Cameroon Ministry of Agriculture (1982).

Survey Method

The survey covered the entire Republic of Cameroon and included 40 administrative divisions of the network of the Ministry of Agriculture's Extension Service.

Three survey methods were used. First, a postal questionnaire was pretested (1981 survey) and modified. This questionnaire was sent to Divisional Chiefs of Agriculture with instructions to forward copies to all their Chiefs of Post (extension agents), who interviewed the farmers and completed the questionnaires. Second, a special group of respondents was asked to give detailed descriptions of processing and preservation techniques of root and tuber crops peculiar to their region. Such techniques had been identified by the first survey method. Third, visits were made to some root crop processing units to study (and confirm) the methods described in the questionnaires.

A total of 1000 questionnaires (25 per division) were used; 567 people (395 women, 172 men) were interviewed. Responses were received for 917 questionnaires (91.7%). The following aspects were considered in the survey: harvesting patterns or frequencies; fresh storage techniques; fresh storage problems; traditional processing techniques; utilization; and commercialization.

Results

Cassava

Cassava is extensively cultivated throughout the Cameroon. Production, however, is higher in the southern regions. Individual farm holdings in these regions are small (0.1–3.0 ha).

Two or more cultivars are grown in each cassava area and are separately utilized. Sweet cassava can be boiled and consumed as a basic vegetable or eaten raw. Bitter cultivars, however, must be processed.

In Cameroon, leaves and tubers of cassava are used to feed humans (Adrian and Peyrot 1970; Eggum 1970). The stems are used as planting material or, in some cases, as fuelwood. Harvested leaves and tubers are stored for only a short time. Harvested tubers are stored for up to 5 days in a cool place and are sometimes covered with fresh leaves. Otherwise, farmers leave the mature tubers in the soil for up to 1 year and harvest as needed. The major obstacle to cassava tuber storage is physiological (Jones 1959). When harvested tubers are stored for long in the humid forest zones, they darken and rot. In the dry savannah, this darkening is accompanied by excessive moisture loss (Booth 1973). Storage pests (insects, rodents, etc.) attack cassava tubers during storage but are easier to control than the physiological factors.

Processing

Unlike other tubers, cassava is often processed before consumption because, throughout the ages, farmers have recognized the toxic nature of unprocessed or improperly prepared cassava. (Collard and Levi 1959; Akinrele 1964). A wide variety of processed cassava products are common in Cameroon.

- *Unfermented fufu*, popular in the north, is obtained by chipping, drying, and milling the flesh of cassava tubers.
- *Fermented fufu*, more popular in the west, south, and east, is obtained by fermenting the tubers, drying the pulp, and milling into a fine flour (Numfor 1984).
- *Water fufu* is the fermented pulp that has not been dried; it is prepared directly and eaten.
- *Myondo* and *bobolo* are fermented pulp that is ground into a fine paste and tied in banana or Zingiberaceae leaves.
- *Mentoumba* is a cake obtained from fermented pulp mixed with other ingredients and wrapped in Zingiberaceae leaves.

- *Cooked chips* are made by boiling, chipping, and soaking bitter and waxy cassava in water, which is constantly changed, for several days.
- *Saboulou* is a local detergent made from cassava starch, palm kernel oil, and wood ash filtrate boiled together to give a solid mass.
- *Arki* is an alcoholic beverage made by fermenting cassava pulp with malt and distilling the liquor.

COCOYAM

Our survey considered two species of cocoyam: *Xanthosoma sagittifolium* (macabo) and *Colocasia esculenta* (taro). Three cultivars of macabo have been identified in the country (CNRCIP 1982): white, red, and yellow. However, the number of taro cultivars in Cameroon is unknown.

Cocoyams are usually harvested when the leaves begin to senesce (8–12 months after planting). In regions where the rains do not immediately follow crop maturity, corms can be left in the soil and harvested as needed. Otherwise, the crop is completely harvested and any excess is stored.

Cocoyams intended for storage are harvested carefully to avoid injuring the corms and cormels, which are exposed to sunlight for 2 or 3 days to encourage suberization. Tubers are stored in a dry, cool place either covered with dry leaves or in a hole lined with dry banana or plantain leaves. In some cases, wood ash is sprinkled over the tubers (probably to serve as a fumigant or pesticide). The heap is covered with other dry leaves. In some regions, the heap is covered with dry soil to form a mound about 50 cm above ground level. Under such conditions, cocoyams keep up to 4 months. The major problems encountered during storage are rotting and sprouting. Fresh cocoyams are not usually palatable to insects or rodents; therefore, animals are not a major problem to fresh cocoyam storage.

PROCESSING

After some processing, the corms, cormels, and young leaves of cocoyams are consumed as basic vegetables. They are either boiled, roasted, or baked. Most processed cocoyam is consumed immediately or stored for a short time. One common product of taro is a white paste (achu) that is obtained by boiling, peeling, and pounding the cormels.

YAM

Yams intended for prolonged storage are harvested in such a way as to avoid wounding the tubers. Otherwise, only sound tubers are stored.

Unlike other parts of West Africa, no special storage structures for yams (such as barns) are common in Cameroon. Generally, after harvest and selection, the suberized tubers are simply placed in a cool, dry place in the house or under a tree and covered with dry leaves. In the Adamawa, West, and Northwest provinces, however, yams are commonly stored in pits. This technique involves digging a 1–2 m diameter hole, lining it with dry leaves or dry grass, and placing the selected tubers inside. In some cases, wood ash is sprinkled over the heap. The heap is then covered with dry leaves or dry grass and, in some cases, dry soil is used to build a mound on top of this structure. Yams stored in this way can keep for up to 4 months. Another method of yam tuber storage involves placing the yams on rafters built along the walls of the house.

The method of storage depends on the type of yam and its intended use. For example, *Dioscorea dumetorum* that is intended for consumption is rarely stored for long because its tubers harden in storage. However, because hardening has no apparent effect on sprouting, tubers intended as seed material can be stored for extended periods (Lyonga et al. 1974). Two local cultivars of *D. dumetorum* are available in Cameroon: Jakiri, which is high yielding but does not store well, and Muyuka, which is low yielding and can be stored for a short time. Other storage problems of yams are sprouting, rotting, and dehydration. Drying tubers in the sun and dusting them with wood ash seems to reduce the incidence of rotting. Storing tubers in a cool place reduces dehydration (Hawkes 1970).

PROCESSING

Yams undergo little or no processing before consumption and are mostly consumed as a basic vegetable. Processing into yam flour, which is common in other West African countries, is not popular in Cameroon. Rather, yam fufu is made by peeling, boiling, and pounding to obtain a stiff paste, which is eaten with sauce. Another product, the yam doughnut, is also common.

SWEET POTATO

Of the four major root crops commonly grown in Cameroon, sweet potatoes are the least cultivated (Table 1). The reasons for this are mainly cultural. In many regions, sweet potato was considered as "dog food" and used only for feeding animals. An increased awareness of the nutritional value of this crop has changed the situation, however, and sweet potato cultivation for human consumption is expanding.

Traditionally, sweet potato is harvested as needed and there is no fixed time for harvesting the crop after

maturity. When harvesting is delayed, however, damage by sweet potato weevils increases.

Storage

The major obstacles to sweet potato storage in Cameroon are pests and sprouting. Traditionally, after harvest, only sound tubers are stored. The tubers are exposed to sunlight for 2 or 3 days to suberize; they are then put in a dry place or in a basket that is kept in a dry place and covered with banana leaves or grass. Tubers may also be put in a hole lined with dry leaves in a dry place. Wood ash is sprinkled on top of the tubers and the heap is covered with dry leaves or dry grass. In rare cases, a mound of dry earth is built on top of the heap. Under these conditions, the tubers keep up to 3 months. When the stored tubers are inspected, sprouted tubers are removed for consumption and rotten tubers are discarded.

Processing

The traditional transformation of sweet potatoes into other products is limited. Sweet potatoes are usually consumed as a basic vegetable by steaming, frying, roasting, or baking. However, a few processed products are common in Cameroon.

- *Chips* of dried sweet potato are a famine security product common in the Northwest, West, Adamawa, and North provinces. The tubers are peeled, boiled, sliced, and dried over the hearth. The chips, which measure about $0.5 \times 3 \times 1$ cm, can be stored in a basket, calabash, or other utensil for long periods (up to 1 year). When needed, the chips are consumed directly.
- *Cake* is prepared by, first, peeling, washing, grating, and pressing the tubers to remove the juice. The pulp is then pounded or ground on a stone to obtain a fine paste, which is mixed with ingredients such as salt, crayfish, pepper, oil, etc. This mixture is wrapped in banana leaves that have been wilted over a flame. The wraps are then steamed for about 1 h in a pot whose bottom has been lined with sticks and some water, which does not touch the wraps. The product is consumed directly.
- *Dolo* is a nonalcoholic sweet potato beverage that is popular in parts of the West, Northwest, and Adamawa provinces. Tubers are peeled, washed, sliced, dried for 1 or 2 days, and boiled for 1 or 2 h in enough water to flood the chips (this level is maintained by constant addition). The liquor is then filtered, put in calabashes or bottles, and cooled. The product can keep 1 or 2 weeks if it is periodically boiled to prevent fermentation.
- *Flour* is produced on a very minor scale in some regions of Adamawa Province. The tubers are peeled, chipped, and dried in the sun for 2–4 days. Dried chips are pounded into a fine flour that can be used alone or mixed with other flours to make fufu.

Research Priorities

This survey of traditional postharvest technologies of root and tuber crops in Cameroon indicates that postharvest technology research should focus on the following aspects. First, simple storage techniques and structures must be developed. The production of root and tuber crops is indirectly constrained by the lack of effective storage techniques and structures. Most farmers are easily discouraged when, after a bumper harvest, most of the crop is lost during storage. With the growth of cities and the higher demand for food in the rural areas, any effective techniques and structures for the storage of root and tuber crops will promote increased production.

Second, improved handling and processing techniques must be developed with emphasis on nutrition, hygiene, and quality standards. There is a wide range of traditional skill for handling and processing root and tuber crops; however, these techniques need improvement. As people become aware of nutrition, hygiene, and quality standards, traditionally processed foods tend to be less desirable than imported foods. The emphasis, therefore, should be on developing existing local technologies.

Third, root crops could serve as raw materials for the development of industrial products. Cassava, for example, is a source of good-quality starch for the pharmaceutical, textile, and food industries, and the aroids contain chemicals that are important in medicine.

Fourth, new, competitive, fast-food products should be developed. Most traditional products require a lot of time to prepare. Therefore, the general tendency is to buy imported foods that are easier to prepare. Root and tuber crops, however, offer a good base for the development of fast-food products.

Fifth, animal feeds must be developed. Root and tuber crops, particularly their shoots, offer useful material for animal feeds. Traditionally, the shoots of these plants have been used minimally, although they are rich in good-quality proteins and vitamins.

Basic data on root and tuber crops are required. Some information exists on the proximate composition of root crops. More information is needed, however, on the variability of these data with crop variety, environment, age, and storage and processing. Nutritional studies are also needed.

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PIT-CURING TECHNIQUE FOR PROLONGING THE SHELF LIFE OF YAM TUBERS

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Burying bruised yam tubers in pits lined with wood shavings was evaluated as a prestorage tuber-curing treatment. The aim was to reduce weight loss, rotting, and sprouting during storage. Burying the tubers for 15 days before storage in the yam barn produced the best results: weight loss and rotting were reduced by 38 and 54% after 4 months of storage, respectively, when compared with uncured tubers. As the duration of pit curing decreased, weight loss and rotting during storage increased. Uncured tubers had the highest weight loss (89.7%) and rot incidence (100%) after storage. The incidence of sprouting of cured tubers during storage increased as the curing duration increased. After 3 months of storage, tubers cured for 3 days showed 77% sprouting and those cured for 15 days showed 92% sprouting. This study indicates that burying bruised tubers in soil pits for 11–15 days is an effective curing technique for prolonging the shelf life of yam tubers.

Yams (*Dioscorea* spp.) are an important staple food crop of the tropics. Production is seasonal and the tubers are stored for up to 7 months after harvest to make them available throughout the year. During this prolonged storage, considerable weight loss occurs. Losses of up to 50% after 6 months storage have been reported (Booth 1974; NRCRI 1982). Storage losses are mainly due to tuber dehydration, respiratory loss of carbohydrate, tuber sprouting, and microbial decay (Coursey 1961).

Yam tubers are bulky and prone to bruising and wounding during harvesting and handling. The wounds and bruises provide entryways for rot-causing organisms, which cause decay and dehydration. The effects of tuber injury can be minimized by curing. Curing is a wound-healing process and has been reported to be one of the simplest and most efficient means of reducing postharvest losses (Booth 1978; Passam 1982). It involves exposing tubers for short periods to high temperatures and high relative humidities to promote wound healing through suberization and wound periderm formation. The new cork layer formed helps to retard the rate of dehydration and acts as a barrier to infection by microorganisms (Priestley and Woffenden 1923).

Curing freshly harvested tubers at 30–40°C and 62–100% relative humidity for 1–4 days controls postharvest losses in yams (Gonzalez and de Rivera 1972; Adesuyi 1973; Thompson et al. 1974). However, recommended curing practices using a controlled environment have not been adopted by peasant farmers because of the lack of cheap, readily available curing techniques. A simple technique used by farmers to cure yams involves covering tubers with dried grass or tarpaulin (Booth 1978) in the open at ambient temperatures for about 4 days before storage.

A survey of yam storage practices in Nigeria by the National Root Crops Research Institute, Umudike, in 1982 discovered that some farmers in Bendel State bury harvested tubers in soil pits for several days to cure them before storage. A previous study on pit curing at Umudike showed that yams buried in pits for 7 days after harvesting had only 3.3% rot after 6 months storage; uncured tubers showed 20% rot (Onwujiobi 1983). This study, however, investigated a curing duration of 7 days. Therefore, the present study was undertaken to examine the effects that various curing durations have on the weight loss, rotting, and sprouting of injured yam tubers in storage.

MATERIALS AND METHODS

Tubers of *D. rotundata* cv. Nwopoko were collected from the yam barn of the National Root Crops Research Institute, Umudike, Nigeria. Forty tubers were used for each curing period and the control. The curing treatments involved burying freshly bruised tubers in a soil pit for 3, 7, 11, and 15 days. The tubers were bruised on opposite sides by rubbing them against the rough edge of a sterile cement block before placing them in the pit.

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The pit used as the curing chamber was 2.5 m × 1.5 m × 1 m. The floor of the pit was lined with wood shavings before placing the tubers inside. After packing the tubers inside the pit, they were covered with another layer of wood shavings and a thin layer of soil. A thermohydrograph was placed in the curing chamber to monitor temperature and relative humidity. The top of the pit was finally covered with asbestos ceiling sheets. The average temperature and relative humidity in the pit were 26°C and 92%, respectively.

After each curing duration, a batch of 40 tubers was removed from the pit, carefully cleaned, and divided into 4 replicate groups of 10 tubers each. Each tuber was then weighed and stored on shelves inside a yam barn. Tubers of the control treatment were also weighed prior to storage.

The improved yam barn used for storing the tubers was a roofed and open-sided storage shed measuring 10 m × 5 m × 3 m. The sides of the barn were protected from rodents by a 1 m high barrier, and the rest of the barn was surrounded with strong wire mesh. Sprouting, rotting, and weight loss of each tuber were recorded monthly. Sprouts from tubers were removed after each recording. Tubers were stored for 4 months.

RESULTS

Weight loss was greater in uncured than in cured tubers and the rate of weight loss decreased as the duration of curing increased from 3 to 15 days (Table 1). There was no significant difference in weight loss between the 11- and 15-day treatments, and, except for the 1st month of storage, there was no significant difference in weight loss between the control and the 3-day curing treatment.

Uncured tubers rotted more than cured tubers and rotting decreased as the curing period increased (Table 2). After 4 months of storage, all tubers in the control and 3-day curing treatments had rotted; however, only 53 and 40% rotting was observed in the 11- and 15-day curing treatments, respectively.

Sprouting began early in storage in all treatments, and no significant differences among curing treatments were observed throughout the 4-month storage period (Table 3). Tubers cured for longer periods, however, sprouted earlier than those cured for shorter periods. All tubers in all treatments sprouted during the 4 months of storage.

DISCUSSION

Root and tuber crops are usually cured in controlled-environment chambers. Peasant farmers, however, cannot afford these chambers. A simple and inexpensive method of curing yams in soil pits was studied at Umudike. Onwujiobi (1983) found that burying tubers in soil pits for 7 days prior to 6 months of storage reduced rot incidence by 20% and weight loss by 10%. These results were likely due to wound healing. The present study sought the optimum duration for curing tubers in soil pits. The results indicated that 11–15 days burial was adequate.

The average temperature and relative humidity recorded in the pit (26°C and 92%, respectively) were comparable to the recommended values for curing yams (Gonzalez and de Rivera 1972; Thompson et al. 1974; Booth 1978). The longer than recommended pit-curing duration found to be optimal in this study compensates for the lower than

Table 1. The effect of curing duration (CD) on the weight loss (%) of yam tubers during 4 months of storage.

CD (days)	Storage period			
	1 month	2 months	3 months	4 months
0 (control)	19.9	37.6	47.4	89.7
3	8.9	29.3	46.9	85.4
7	8.3	26.0	34.6	63.5
11	6.2	11.4	17.9	54.9
15	3.4	10.7	15.2	48.4
LSD[a]	9.8	8.6	7.1	10.7

[a]Least significant difference.

Table 2. The effect of curing duration (CD) on the rotting (%) of yam tubers during 4 months of storage.

CD (days)	Storage period			
	1 month	2 months	3 months	4 months
0 (control)	67.5	72.5	90.0	100.0
3	50.0	62.5	72.5	100.0
7	15.0	50.0	55.0	57.5
11	2.5	32.5	37.5	52.5
15	0.0	12.5	27.5	40.0
LSD[a]	17.1	16.5	17.1	11.2

[a]Least significant difference.

Table 3. The effect of curing duration (CD) on the sprouting (%) of yam tubers during 4 months of storage.

CD (days)	Storage period			
	1 month	2 months	3 months	4 months
0 (control)	35.0	82.5	82.5	100.0
3	27.5	72.5	77.5	100.0
7	45.0	72.5	85.0	100.0
11	57.5	87.5	87.5	100.0
15	65.0	90.0	92.5	100.0

Note: At each month, the differences between curing durations are not significant.

usual temperature (26°C vs 32–40°C) in the pit. This view is supported by Passam et al. (1976), who reported that longer curing periods are employed at reduced temperatures. Furthermore, Booth (1978) reported that the time required for proper curing of root crops depends on factors such as variety, type of wound, maturity etc., and that, on average, 7–14 days is adequate.

Even though curing was effective in reducing weight loss and rotting when compared with the control, the differences obtained were higher than expected. This was likely because the tubers used had already been in storage for over 1 month. Booth (1978) suggested that tubers should be cured immediately after harvest for the curing to be effective.

The increase in sprouting observed as the curing duration increased (Table 3) could be due to the prolonged exposure of buried tubers to soil moisture (Onwueme 1973; Been et al. 1975). Therefore, for more effective pit curing, sprout suppressants should be applied to the tubers before curing. Gibberellic acid has been effectively used to control sprouting in yams (Passam 1982).

The results of this investigation showed that the conditions that promote wound healing in yam tubers can be obtained in soil pits lined with dry grass straw. The technique is appropriate for peasant farmers wishing to cure their yam tubers prior to storage.

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ACCEPTABILITY, UTILIZATION, AND PROCESSING OF SWEET POTATOES IN HOME AND SMALL-SCALE INDUSTRIES IN GHANA

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The selection criteria, preferred cooking characteristics, and general utilization of sweet potatoes by consumers in Ghana was examined. Techniques for processing sweet potatoes at home and in small-scale industries are also suggested. Consumers prefer smooth, regularly shaped tubers and large or extra-large tubers. Skin and flesh colour are also important selection criteria. In general, sweet potatoes that resemble yams are the preferred staple. Sweet potatoes show potential as a food for children and the flour produced from yellow varieties is potentially useful in baking. Although sweet potatoes cannot be boiled and pounded into fufu, a product similar to gari can be made using cooked sweet potatoes. The processing technique involved in producing this food is perhaps the most potentially acceptable for the home and in small-scale industries in Ghana.

Much attention is currently being given to the preservation and increased use of locally produced foodstuffs in Ghana by the government, the farmers, and the public. Research on sweet potato is being jointly conducted by the Crops Science Department and the Home Science Department of the Faculty of Agriculture, University of Ghana, Accra, Ghana. Recognizing the high potential of the sweet potato, studies are being conducted with the view of promoting sweet potato in the Ghanaian diet. The broad objectives of this study are

- to discover the selection criteria and cooking characteristics preferred by the consumer;
- to develop acceptable sweet potato recipes; and
- to develop techniques for processing sweet potato in the home and in small-scale industries.

SELECTION CRITERIA

In the selection of fresh food products, certain criteria are used by consumers. Sixty consumers from the University community, consisting of self-catering students and workers, were asked to comment freely on the physical attributes they believed important in selecting sweet potatoes. Based on the information obtained, we examined the shape, size, skin colour, and flesh colour of sweet potato.

Sweet potato tubers vary widely among varieties and, in some cases, within variety. Compared with other root crops, sweet potato tubers are less uniform in both size and shape. Consumers preferred smooth, regularly shaped tubers and strongly preferred (90%) large (450–580 g) or extra-large (875–1580 g) tubers. The main reason for these preferences was that such tubers are easier to peel with less peeling waste. Even though peelings could be used as livestock feed, for many households this would mean a reduction in food for the family. The irregularity of sweet potato tubers, therefore, is a problem that should be addressed by root crop breeders.

Besides varietal differences, the age of harvesting affects skin smoothness and tuber size. Therefore, harvesting at the appropriate stage of maturity is important in achieving consumer satisfaction.

Surface and internal colours are important selection criteria; in the market, many consumers will have the vendor cut open sample tubers before deciding to purchase. Generally, the skin colour of sweet potato tubers ranges from cream–yellow to red–purple. There are five categories of both skin and flesh colour that consumers prefer (Table 1). The consumers in this study preferred tubers with cream to pale yellow, red, or purple skin. They indicated that the orange colour was "interesting" but "strange" and disliked varieties with mixed coloration. Pale yellow and very white flesh, especially that which does not darken after peeling, were preferred.

COOKING CHARACTERISTICS

Consumers considered colour, flavour, and texture as important characteristics in a staple dish. Quality characteristics and acceptability tests were

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Table 1. Consumer preference for peel and flesh colour of raw sweet potato tubers.

Colour	Score[a]	Sweet potato variety
Peel		
Orange to red	22	TIb 11(102), TIb 10(3), TIb 2(26), cv. Regal
Cream to pale yellow	66	TIS 5081, ITS 2, TIb (62), VAR 3
Red to purple	69	TIS 9250, TIS 2532, TIS 3017
Deep purple	66	TIS 1145, TIS 2544, TIS 2534, TIS 2498, TIS 5125
Yellow and purple	32	TIS 1487, TIS 1499
Flesh		
Orange	32	TIb 11(102), TIb 10(3), TIb 2(26), cv. Regal
Pale yellow	66	TIS 5081, ITS 2, TIb (62), VAR 3
Pinkish	46	TIS 9250, TIS 2532, TIS 3017(3)
Predominantly white[b]	53	TIS 1487, TIb 1499
White	58	TIS 1145, TIS 2498, TIS 2544, TIS 5125, TIS 2534

[a]Colours were ranked in order of preference by 17 consumers (i.e., from 1 [least preferred] to 5 [most preferred]), and the recorded score is a total of these rankings.
[b]Lightly mixed with other colours.

conducted on 18 sweet potato varieties. Colour, texture, flavour, and overall acceptability were assessed by a trained 20-member panel. Panelists preferred the very white and yellow varieties. The translucent, darkened, or orange varieties were unacceptable.

The texture of the cooked tubers ranged from mealy through intermediate textures to waxy forms. Varieties with a mealy texture were rated highly for their yamlike quality and were judged agreeable as a staple dish that could be used in place of yam or cassava and eaten with soups or sauces. The stringy and waxy nature of some varieties was unacceptable.

Most local varieties are very sweet and this is a major obstacle to the acceptance of sweet potato as a staple. Panelists preferred the less sweet varieties. One of the oldest uses of sweet potatoes in Ghana, however, is in the sweetening of corn dishes such as porridge and aboloo. Therefore, although efforts are being made to breed less sweet varieties, some very sweet varieties should be preserved and bred for this purpose.

In general, varieties that resemble yams (with white or yellow flesh, a mealy texture, and less sweetness) are the preferred staple. The persistent desire for yamlike qualities in sweet potato should be addressed by breeders and home economists in Ghana.

General Utilization

Having identified the more acceptable varieties, various recipes were developed (Osei-Opare 1985). Sweet potatoes were incorporated into dishes that traditionally used other root crops, and new recipes, which will cater to a variety of tastes, were developed. Even though yamlike varieties were used, the preparation was different from that of yams. Because of their short cooking time and softer texture, for example, less water and stirring were required during cooking to maintain shape and less manipulation in mashing was required where mealiness was a desirable characteristic.

Many families are reluctant to prepare separate meals for the young children, but sweet potatoes have two distinct advantages in this area. First, the sweet potato is a potential favourite with children because of its soft texture and sweet flavour. Second, the smaller size of the tubers lends itself to use in children's meals; for the same purpose, pieces must be cut off larger tubers, shortening their shelf life.

The nutritional value of sweet potato is similar to that of other root crops (FAO 1968). The food energy value, however, is about one-quarter to one-third more than that of yam or cocoyam, but is below that of cassava. Sweet potato is a good source of vitamin C and, because they cook relatively quickly and may be boiled without peeling, losses during cooking are minimal. The yellow pigment in some varieties is not only aesthetically appealing to consumers, but also a source of vitamin A.

The partial replacement of wheat flour with root crops and other nonwheat crops has occupied the Food and Agriculture Organization and other organizations for a long time. The principal aim of the composite flour program is to develop high-quality food products using locally available raw materials to reduce the costs of imported wheat. Most composite flour projects have been centred around the use of important staples within the locality. In countries with unstable food production, a poor harvest of staple crops will adversely affect any composite flour program. In Ghana, shorter duration crops such as sweet potato offer a potential in this direction because they are not used as staples.

The bakery products most commonly consumed in Ghana are bread, doughnuts, and pastries. Preliminary work with sweet potato has shown that yellow varieties retain a good colour in their cooked state and were more useful as an addition to wheat in baking. Varieties ITS 2 (cv. Frema) and VAR 3 blend well with wheat for such products and a 20% substitution of wheat flour with sweet potato flour in bread gives acceptable quality (Singh et al. 1953; Sammy 1970). For bread, sweet potato tubers were used cooked and mashed, cooked and drum dried, or

sun dried. When precooked sweet potato (cooked, mashed, and drum dried) was mixed with wheat, the products had a golden brown crust, a thin and uniform cell structure of crumb, and were tender. Bread from a blend of sun-dried sweet potato and wheat, however, was dull in colour, had a thick hard crust, a slightly coarse cell structure, and was generally less tender (Bortey 1982).

Doughnuts from a blend of precooked sweet potato and wheat, at substitution levels of 25 and 40% for cake and yeast types, respectively, were preferred by consumers over all-wheat products. Sweet potatoes gave these products a rich, soft texture and colour (Ntim 1981; Osei-Opare 1985). Consumers wrongly believed the sweet potato products contained more eggs, margarine, and sugar. In a 2-day exhibition, food demonstrations were held for the benefit of the public. After using sweet potatoes in composite flour for various baked goods, some commercial bakers considered the characteristics of these products an added marketing advantage, in addition to cutting costs and extending the limited wheat flour supply.

Processing Techniques

With a high yielding, early maturing food crop such as sweet potato, home and small-scale processing can generate extra income for women and supplement the family food supply in the lean season. Because of inadequate storage and processing facilities, however, sweet potato production will not reach the desired level. Recognizing these problems, efforts are being made to develop techniques for processing sweet potatoes in the home and in small-scale industries.

Various sweet potato preparations were made from cooked and mashed, and raw sun-dried variety ITS 2. When raw slices were dried in a cabinet solar dryer, the yellow colour was lost as a result of the breakdown of carotenoid pigments. The resulting product was off-white. Apart from this loss of colour, sweet potato chips were brittle and difficult to mill into flour. An initial hand milling using a pestle and mortar was required before passing the pieces through a corn mill to obtain flour. The flour was rather coarse, grey, and had a slightly off flavour. This product may be used in composite flour for breads, biscuits, etc.

Another product was made by grating raw sweet potatoes, squeezing out the juice, and drying in an oven and a solar dryer. Drying was faster and the liquid squeezed out settled to extract starch. The resulting product were light flakes with a pleasant aroma; they could be used in porridges, sauces, and bakery foods. Perhaps the most potentially acceptable processing technique is making a product similar to gari using cooked sweet potatoes. Because precooked sweet potato was found to give better quality products in composite with wheat, an attempt was made to find a more suitable way of processing a precooked product with good storage characteristics using a simple technology that could be practiced at home and in small-scale industries.

A suitable heat source is a first requirement for ensuring fast drying to avoid fermentation and food loss, which usually occurred when the product was sun dried. A precooked product requires hygienic handling to make it safe for human consumption and to give it a longer storage life. Two fast-drying techniques have been employed: oven-drying at 50–60°C and slow roasting in heavy, galvanized iron frying pans, a method already used by women for making gari. The result is a gritty, garilike product with a beautiful yellow colour; the product swells with rehydration. It seemed suitable in many ways for the preparation of gari dishes.

The product can be milled into flour and used in baked goods in composite with wheat; this could encourage women who already handle baked goods to get access to sweet potato flour. One of the main drawbacks in promoting sweet potatoes as a staple is that they cannot be boiled and pounded into fufu, as can yam, cocoyam, and cassava. Sweet potato flour from either raw dried or precooked tubers mixed with starch has an immense potential for producing a fufulike product and, therefore, could contribute in the quest for a more convenient and hygienic way of making this well-loved dish.

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ABSTRACTS

RECENT ADVANCES IN YAM STORAGE TECHNOLOGY

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Previous theoretical analysis has indicated that an adiabatic environment would be ideal for the prolonged storage of yam tubers. To understand the main characteristics of such an environment, the catabolism of stored starch was studied under aerobic and anaerobic conditions. Results showed that the anaerobic condition closely approximated the required adiabatic environment, that, by energy control, aerobic conditions could be made to approximate the adiabatic environment, and that alternating from aerobic to anaerobic conditions gave a practical adiabatic environment. These conclusions were tested with white yam tubers (*Dioscorea rotundata* cv. Nwopoko). One group of tubers (control) was continuously kept in air (aerobic); the second group was alternated from 10 days of aerobic storage to 7 days of anaerobic storage for 18 weeks (adiabatic). The control tubers lost a total of 15% of their weight; the adiabatic tubers lost only 3% of their weight. These results give a scientific basis for the use of adiabatic environments in the prolonged storage of yam.

BIOCHEMICAL ASPECTS OF WOUND HEALING IN YAMS

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The effect of wounding white yam (*Dioscorea rotundata* Poir) tubers on the activities of some enzymes and the concentrations of selected tuber metabolites was investigated. Tuber lipolytic acyl hydrolase activity decreased after wounding, disappearing by the 4th day; lipoxygenase peroxidase and polyphenol oxidase, however, increased their activities 2–9 times, with maximum values on the 4th and 5th days after wounding, respectively. Lipoxygenase and polyphenol oxidase activities measured in the proximal half of tubers were much higher than corresponding activities in the distal half, suggesting the existence of a wound-dependent activity of a concentration gradient for some tuber enzymes. The increase in lipoxygenase activity at the wound site was localized. The application of tetracycline during the early stages of wound healing substantially reduced the increases in activity of polyphenol oxidase and lipoxygenase. Free amino acid, total polyphenol, and ascorbate concentrations in the tuber increased in response to wounding. After 24 h, however, the concentration of free amino acids had declined.

CONTROL OF POSTHARVEST BIODETERIORATION OF YAM (*DIOSCOREA ROTUNDATA*) WITH THE NEMATICIDE VYDATE L®

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Postharvest losses of yam tubers as a result of nematode infestation from the soil during cultivation and the subsequent formation of disease complexes with fungi, bacteria, and viruses is a worldwide problem. Such losses reduce the annual world yam output by about 26%. In Nigeria, root-knot nematodes are a major

contributor to postharvest yam losses. This study investigated the effectiveness of the nematicide Vydate L® in controlling the damage caused by root-knot nematodes. Infested tubers of *Dioscorea rotundata* were dipped in various concentrations of Vydate L® for various times with or without hot water. Sprouting, weight loss, rotting, and loss of edible portions were monitored for 5 months. Chemotherapy with Vydate L® proved to be an economical and safe method of controlling postharvest nematode damage in ware yam tubers.

A THERMODYNAMIC ANALYSIS OF YAM (*DIOSCOREA* SPP.) TUBER DEGRADATION IN STORAGE

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Yam tuber storage problems relate to the tuber's bulky size, physiology, high moisture content, hygroscopicity, and interaction with its storage environment. Previous research focused on weight losses and tuber properties; only recently have environmental indices been investigated. There has been little work, however, examining the tuber's interaction with its storage environmnet. This paper presents a theoretical analysis based on free energy and entropy changes of the yam tuber in storage. Results showed that the free energy of the tuber decreased in storage as a result of the work contributions of biochemical processes and transport within the tuber. The total entropy change of the tuber had two temperature-dependent components: first, external entropy production transferred externally between the tuber and its storage environment and , second, internal entropy production. The relative significance of each entropy state partly determines the rate of tissue degradation in the stored yam tuber.

SOCIOECONOMICS OF ROOT CROPS PRODUCTION AND UTILIZATION

CASSAVA PEEL UTILIZATION IN POULTRY DIETS

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Three trials with broilers and layers assessed their performance on diets based on cassava peels. In trial 1, diets contained 0, 7.5, 15.0, 22.5, and 30% cassava peels as a replacement for maize for broilers. Cassava peel increased feed intake, reduced body weight gain, and reduced nutrient utilization. In trial 2, diets containing 0, 7.5, 15.0, and 22.5% cassava peel with or without food energy (palm oil) or protein supplementation were fed to broilers. Nutrient supplementation of the cassava peel diets did not greatly affect the biological performance of the birds. In trial 3, the inclusion of up to 27% cassava peels in the diet of layers at the expense of maize gave satisfactory feed intake, egg production, and feed per unit egg produced. In each trial, the economy of feed conversion was better on the cassava peel diets than on the maize control diet.

The recent phenomenal rise in the cost of livestock feed ingredients has made it imperative to harness local resources that have hitherto been wasted in agroindustries as components of compounded diets for livestock. The mechanization of gari production in Nigeria has resulted in the production of large quantities of tuber peels and wasted small-sized tubers, which are difficult to process. In many parts of Nigeria, these by-products are discarded.

The peel accounts for between 10 and 13% of the tuber by weight (Tewe et al. 1976). Longe et al. (1977) reported the metabolizable energy of cassava peels (rind alone) to be 1.52 kcal/g; Tewe (1984), however, reported the value for peels from gari-producing factories to be 2.16 kcal/g (1 cal = 4.19 J). The value of Tewe (1984) is higher because of the additional small tubers and the pulp that adheres to the peel during peeling. Studies on pigs (Tewe and Pessu 1982; Tewe and Oke 1983) showed that peels can constitute up to 40% of the compounded diet of pig growers.

The present study evaluates the effects of replacing maize with sun-dried cassava peels on the performance and nutrient utilization of broilers and layers.

PROCEDURE

Fresh cassava peels collected from Texaco Gari Factory (Texagri) near Abeokuta, Nigeria, were dried in the sun to about 10% moisture content on cemented floors where they were turned daily with rakes. The dried peels were subsequently milled into flour and used in three trials.

BROILER STUDIES

TRIAL 1

Two hundred 1-day-old, Anak breed chicks were randomly alloted into 10 groups of 20, and each group was kept in a metallic brooder cage. Each treatment was replicated twice, giving five dietary treatments: one maize control (diet 1) and four diets with cassava peel partially replacing maize (diets 2–5). Levels of incorporation of cassava peels were 0, 7.5, 15.0, 22.5, and 30% of maize component in diets 1–5, respectively, for both the starter and finisher phases. Feed and water was provided ad libitum. Birds were reared for the first 6 weeks on the starter diets in the metallic brooder cages and subsequently transferred to floor pens with litter until the 10th week. Birds were given all the routine vaccinations. Feed intake and body weight were recorded weekly. Balance (digestibility) studies were carried out at the end of weeks 5 and 10 using all birds at the starter phase and four birds per replicate at the finisher phase.

TRIAL 2

Five hundred 1-day-old, Anak broiler chicks were raised on a 24% crude protein starter diet for the first 6 weeks. After this, 400 chicks were alloted into 20 groups of 20 in floor pens. The dried and milled cassava peels were incorporated into nine test diets (diets 2–10). Diet 1 was the maize control. Cassava

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peels were incorporated at 7.5, 15.0, and 22.5% at the expense of maize and, for each level of cassava peel incorporation, the food energy and protein deficiencies resulting from cassava peel inclusion were augmented with palm oil and protein concentrates (groundnut cake, fish meal, and blood meal), respectively. Management in the finisher phase was as described for trial 1.

Layer Study

Trial 3

Two hundred 24-week-old, point of lay Babcock birds were randomly distributed into 10 groups of 20. They were fed a maize control diet or a diet in which 68.2, 136.4, 204.6, or 272.8 g maize/kg was replaced with cassava peels prepared as in the broiler studies. Each treatment was replicated twice. Weekly feed intake, egg production, and body weight were recorded for 10 weeks. Balance studies were carried out on six birds per replicate after the feeding trial to assess nutrient utilization.

Chemical Analysis

Feeds and ovendried feces from all phases were subjected to proximate analysis (AOAC 1970). Gross energy of all samples was determined using the ballistic bomb calorimeter.

Statistical Analysis

Data were subjected to variance analyses and Duncan's multiple-range test was used for evaluating the significance between treatment means (Steel and Torrie 1960).

Results

Broiler Studies

Trial 1

The performance of broilers on diets 1 and 2 was similar in all cases; diet 2, however, showed a higher mortality (Table 1). Diet 3 was superior to diet 5 in terms of feed intake and body weight gain. Generally, perfomance traits were better on diets 1 and 2 than on the other diets. Cost per unit weight decreased from diet 1 to 5. Feed cost per kilogram live weight gain was lowest in diets 1 and 2 in the starter phase. In the finisher phase, diet 1 was superior. Metabolizable energy decreased from diets 1 to 5 in both the starter and finisher phases. Nitrogen retention in the starter phase also decreased from diets 1 to 5; in the finisher phase, however, nitrogen retention was slightly higher in diets 1 and 2.

Trial 2

Feed intake was higher ($P < 0.05$) on diets 3, 6, and 10 than on diet 8 (Table 2). Body weight gain was lowest ($P < 0.05$) on diet 8. No deaths were recorded

Table 1. Performance, nutrient utilization, and economy of production in broilers fed varying dietary cassava peel levels.

Parameter	Cassava peel level (%)[a]				
	0.0 (1)	7.5 (2)	11.5 (3)	22.5 (4)	30.0 (5)
Starter phase					
Weekly feed intake/bird (g)	292.3	290.1	291.8	310.1	311.6
Weekly weight gain/bird (g)	132.8a	130.1a	129.6ab	126.3ab	120.1b
Feed intake/weight gain	2.2	2.2	2.3	2.5	2.6
Mortality (%)	2.5	5.0	10.0	15.0	15.0
Nitrogen retention (%)	73.1	71.2	58.3	68.2	66.7
Protein efficiency ratio	1.80	1.80	1.89	1.75	1.66
Feed cost/live weight gain (NGN/kg)[b]	0.98	0.97	1.00	1.01	1.11
Metabolizable energy (kcal/g)[c]	2.81	2.76	2.71	2.68	2.62
Finisher phase					
Weekly feed intake/bird (g)	786.5b	791.3b	773.6b	813.2a	850.7a
Weekly weight gain/bird (g)	218.4a	219.3a	206.1ab	184.3b	180.1c
Feed intake/weight gain	3.6c	3.6c	3.8b	4.4a	4.7a
Mortality (%)	0.0	5.2	8.3	8.8	8.8
Nitrogen retention (%)	66.4	66.2	64.8	65.1	64.1
Protein efficiency ratio	1.34a	1.42a	1.38a	1.22b	1.14b
Feed cost/live weight gain (NGN/kg)[b]	1.38	1.44	1.56	1.81	1.85
Metabolizable energy (kcal/g)[c]	2.99	2.93	2.88	2.82	2.77

Note: Values in the same row followed by the same letter(s) are not significantly different ($P > 0.05$).
[a]The diet number is shown in parentheses.
[b]In February 1987, 2.6 Nigerian naira (NGN) = 1 United States dollar (USD).
[c]1 cal = 4.19 J.

Table 2. Performance, nutrient utilization, and economy of production of finisher broilers fed varying dietary cassava peel levels.

Parameter	Cassava peel level (%)[a]								
	0.0 (1)	7.5 (2)	7.5 (3)	7.5 (4)	15.0 (5)	15.0 (6)	15.0 (7)	22.5 (8)	22.5 (9)
Weekly feed intake/bird (g)	780.0ab	790.0ab	810.0a	800.0ab	810.0ab	810.0a	770.0ab	740.0ab	780.0ab
Weekly weight gain/bird (g)	220.0a	243.3a	296.8a	243.3a	216.6a	226.6a	223.3a	160.0b	220.0a
Feed intake/weight gain	3.5ab	3.2ab	3.4ab	2.3b	3.7ab	3.6ab	3.4ab	3.6a	3.5ab
Mortality (%)	5.0	5.0	0.0	5.0	2.5	0.0	2.5	10.0	5.0
Nitrogen retention (%)	65.0	66.3	64.9	66.9	65.3	64.4	67.3	66.2	65.5
Protein efficiency ratio	1.40ab	1.51a	1.47a	1.49a	1.33ab	1.44ab	1.43ab	1.08c	1.40ab
Feed cost/live weight gain (NGN/kg)[b]	1 45	1.33	1.26	1.32	1.42	1.22	1.23	1.81	1.19
Metabolizable energy (kcal/g)	2.91	2.93	2.80	2.85	2.93	2.70	2.76	2.91	2.64
Crude protein (%)	20.21	20.36	19.84	20.40	20.16	19.47	20.26	20.05	20.10

Note: Values in the same row followed by the same letter(s) are not significantly different ($P > 0.05$).
[a]The diet number is shown in parentheses.
[b]In February 1987, 2.6 Nigerian naira (NGN) = 1 United States dollar (USD).

on diets 3 and 6, while diet 8 gave the highest mortality. The feed cost per kilogram live weight gain was highest on diet 8; all other test diets showed a lower cost than the control. Metabolizable energy was highest on the control diet and on diets 2, 5, and 8, which were supplemented with palm oil and protein concentrates. The unsupplemented test diets (3, 6, and 9) showed the lowest metabolizable energy levels. Nitrogen retention did not show any clear trend.

LAYER STUDY

TRIAL 3

Weekly feed consumption was significantly higher ($P < 0.01$) on diet 5 than on the other diets (Table 3). Body weight gain decreased from diets 1 to 5. The number of eggs produced per week was highest ($P < 0.01$) on diets 1 and 3. Feed consumed per unit egg produced was highest on diet 3 and lowest on diet 1. Metabolizable energy was lowest ($P < 0.05$) on diet 5, nitrogen retention decreased from diet 1 to 5, and cost of feed per unit egg produced was lowest on diets 4 and 5.

DISCUSSION

TRIAL 1

Feed intake increased and metabolizable energy decreased with higher dietary levels of cassava peels. Because birds eat primarily to satisfy their energy requirements, more feed was consumed on cassava peel diets. The metabolizable energy of this waste product ranges from 1.52 to 2.16 kcal/g, compared with 3.4 kcal/g for maize (Tewe and Pessu 1982). The economic performance of broilers on cassava peel diets (except diet 2) in the starter phase was inferior to their performance on the control diet in terms of feed cost per kilogram live weight gain. This is due to the higher mortality on the cassava peel diets. Postmortem diagnosis showed that death was due to pulmonary congestion, nephritis, entaritis, or, in some cases, New Castle disease. Although these causes of death do not relate specifically to cyanide toxicity, birds raised on cassava peels might be more susceptible to diseases than those on corn-based diets because of the hydrocyanic acid content and growth of toxic microorganisms on the sun-dried cassava peels (Clerk and Caurie 1968; Tewe et al. 1976).

TRIAL 2

The effects of food energy and protein supplementation on the performance of the birds in trial 2 showed no clear trend (Table 2). However, birds tended to consume less of the 22.5% cassava peel diets (8 and 9). This might have been due to increased dustiness (Oke 1978). The body weight gain was remarkably lower on diet 8. Palm oil and protein supplementation raised the price of feed per unit weight. The cost of feed per kilogram live weight gain, however, was lower for the cassava peel diets than for the maize control diet (except diet 8). Therefore, there is cost advantage in using cassava peel diets (up to 22.5%) at the broiler phase. Palm oil and protein supplementation reduces the cost benefit to the producer.

TRIAL 3

Performance as measured by feed intake and body weight gain was poorer on the cassava diets because of the lower metabolizable energy and the presence

Table 3. Performance, nutrient utilization, and economy of production in layers fed varying dietary cassava peel levels.

Parameter	Cassava peel level(%)[a]				
	0 (1)	6.82 (2)	13.64 (3)	20.46 (4)	27.28 (5)
Cost of feed[b]					
NGN/t	359.3	337.4	314.3	291.8	269.3
NGN/100 eggs	5.6	5.4	6.4	4.7	4.8
NGN/kg eggs	1.0	2.0	1.2	0.9	0.9
Weekly feed consumption/bird (kg)	0.80b	0.70c	0.74d	0.78b	0.84a
Weekly crude protein intake/bird (kg)	0.14a	0.13b	0.13b	0.13b	0.14a
Weekly cyanide intake/bird (mg)	0.00e	14.74d	28.32c	44.78b	63.92a
Average initial body weight (kg)	1.83	1.78	1.73	1.72	1.71
Weekly no. of eggs produced/bird	5.24a	4.92c	5.20a	5.05b	4.70c
Average weight of egg produced (g)	54.89c	55.69b	52.94d	53.67d	56.79a
Feed consumption (kg)/egg produced	0.15	0.16	0.21	0.16	0.18
Feed consumption (kg)/g egg produced	2.81c	2.90b	2.81c	2.93b	3.21a
Metabolizable energy (kcal/g)[c]	3.09a	3.07a	3.05a	3.09a	2.75b
Nitrogen retention (%)	58.48a	47.71ab	47.53ab	45.48ab	39.19b
Weekly body weight gain (g)	0.012	0.009	0.010	0.004	0.005

Note: Values in the same row followed by the same letter(s) are not significantly different ($P > 0.05$).
[a]The diet number is shown in parentheses.
[b]In February 1987, 2.6 Nigerian naira (NGN) = 1 United States dollar (USD).
[c]1 cal = 4.19 J.

of hydrocyanic acid (Tewe 1975; Oke 1978). Egg production on the cassava diets, however, was similar to the control. Because cassava peels are free, their inclusion in the layer diets reduced the feed cost per unit egg produced. Therefore, it is economically sound to include cassava peels in the diet of layers up to 27.28%.

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ABSTRACTS

SOCIOECONOMIC AND UTILIZATION CONSIDERATIONS IN CASSAVA PRODUCTION: A BASIS FOR AGRONOMIC AND GENETIC RESEARCH

A.E. IKPI, University of Ibadan, Ibadan, Nigeria, **TESFAYE GEBREMESKEL AND N.D. HAHN**, International Institute of Tropical Agriculture, Ibadan, Nigeria, **AND J.A. EKPERE**, University of Ibadan, Ibadan, Nigeria

The results of a socioeconomic survey on cassava of 150 farmers from 15 villages in the Oyo Local Government Area of Nigeria are summarized. The decision-making roles of household members in the cassava enterprise are unclear. However, the roles appear highly differentiated and are specific for the various aspects of cassava production, processing, and marketing. The survey showed that cassava was consumed at least once a day in the average household, that cassava consumption patterns varied with the season and the family income, and that cassava contributed to household food security when other food staples were scarce or too expensive. The versatility of cassava enhanced its potential contribution to food security. The survey also showed that cassava farming was a profitable enterprise. Labour and transportation were the most costly resources for the rural farmer in cassava production and processing, accounting for 37.3 and 35.7% of the total cost, respectively. Overall, 72% of labour came from within the family and 28% came from hired help. Women and children were responsible for 71% of the labour. The economic implications of this division of labour are discussed.

SOCIOECONOMIC FACTORS INFLUENCING THE TRANSFER OF ROOT CROPS RESEARCH TECHNOLOGY TO SMALL-SCALE FARMERS IN SOUTHEASTERN NIGERIA

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Some socioeconomic factors influencing the transfer of root crops research technology to small-scale farmers in the southeastern agricultural zone of Nigeria (Anambra, Cross River, Imo, and Rivers states) were examined. The effects of age, education, membership in social organizations, input availability, profitability (productivity) of technology, agricultural extension communication, and agroecological conditions were considered. The study sampled 225 small-scale farmers who had attained the "mass-adoption stage" of the National Accelerated Food Production Project (NAFPP) cassava–maize technology. Correlation analysis (complemented with the concepts of set theory) of the relationships between the selected variables indicated that the transfer of root crops research technology was significantly related to age ($r = 0.38$), education ($r = -0.85$), input availability ($r_s = -1$), and membership in social organizations ($r_s = 0.90$).

COUNTRY REPORTS AND EXTENSION PROGRAMS

YAM EXTENSION WORK OF SHELL: A CASE STUDY

R.O.M. OFFOR[1]

In 1983, the Shell Community Development Project (SCDP) set up a 5-year yam extension program. The intention of the program, which is ongoing, is to establish and promote the production of seed yams in Nigeria. To date, the program has been successful. Over 1984 and 1985, the average recovery of yam setts was 85.7% and farmer participation was 116%. The program is restoring the production and social importance of yams and destroying some of the traditions that have been detrimental to yam production. Problems have been encountered, however. These include tuber preservation and storage, nematode control, planting material supply, fertilizer availability, farmer illiteracy, and getting farmers to further multiply their harvest share before beginning ware yam production. In the future, to achieve the goals of the 5-year program, SCDP will intensify recovery efforts, distribute minisetts instead of macrosetts, attempt to obtain the planting records of farmers who have left the program, and help successful farmers obtain financial assistance to expand production.

According to a survey carried out jointly by Dr M.S. Igben of the Nigeria Institute of Social and Economic Research, Ibadan, Nigeria, and Dr T. Atinmo of the Department of Human Nutrition, University of Ibadan, Ibadan, Nigeria, yam is the most commonly eaten staple food in Nigeria, particularly in the eastern states (Igben and Atinmo 1985). Unfortunately, during the civil war, the yam crop was lost and, after the war, the high cost of seed prevented the resumption of yam cultivation. To assist yam farmers, in 1977, Shell included yam production in its Community Development Project (SCDP) activities, starting with the Uboma Project in the Etiti Local Government Area of Imo State. SCDP currently executes such projects in 14 zones of its areas of operation across Imo, Rivers, and Bendel states. When the Uboma Project was handed over to local residents in 1978, Egbema — a new project area in Imo State — was commenced. Between 1979 and 1983, SCDP made serious efforts to encourage and sustain the production of the crop in many areas of its Eastern Division.

INITIAL PROGRAM

SCDP first went into direct seed production through its Extension Advisers, but it was found that the Advisers could not combine this with their normal extension duties. Thus, multiplication was restricted to Shell's multiplication centre in Bori, Nigeria. Second, SCDP distributed 11 874 seed yams to farmers who planted them whole and harvested ware (food) yams; these were consumed and, once again, the people looked forward to another supply of seed. Third, 88 236 macrosetts were distributed directly to individuals from 1979 to 1983 on the condition that they return 30% of their harvest for sharing among farmers the following year; however, some farmers defaulted because of reported poor harvests. Finally, three cultivars of *Dioscorea rotundata* (white yam) (Ji-Ocha, Aga, and Opoko) were tested for yield, taste, marketability, and tolerance to nematode infections; cv. Opoko gave the best results.

A 5-YEAR PROGRAM

With their knowlege of cv. Opoko and past experience, in 1983, SCDP designed a 5-year yam extension program. To qualify for the program's benefits farmers had to belong to cooperative societies or farmers' associations. Those who did were each given 1000 yam macrosetts (about 200 g) and appropriate quantities of fertilizer and insecticide. Group officials (president, secretary, and treasurer) agreed on behalf of the group that the yam would be grown at the appropriate time and according to the agronomic practices recommended by the SCDP, that the group would return 30% of their harvest to the project for distribution among other farmers the following year, and that farmers' yam shares would be cut into setts

[1]Shell Petroleum Development Company of Nigeria Ltd, Lagos, Nigeria.

Table 1. Distribution and recovery of yam setts in 1984 and 1985.

Zone	1984				1985			
		Recovery				Recovery		
	Distribution (setts)	Expected (seed yams)	Actual (seed yams)	Performance (%)	Distribution (setts)	Expected (seed yams)	Actual (seed yams)	Performance (%)
Afam	18300	6100	4694	77.0	19430	6476	6997	108.0
Assa/Ibigwe	14756	4919	4406	89.6	22896	7632	6143	80.5
Egbema/Oguta	8640	2880	2239	77.7	20848	6947	6743	97.0
Imo River	17000	5666	5122	90.4	23850	7950	5207	65.5
Kolo Creek	—	—	—	—	11800	3933	3729	94.8
Umuechem	12114	4038	4173	103.3	12523	4174	4579	109.0
Yorla	12484	4161	3414	82.0	23250	7750	4523	58.4
Overall	83294	27764	24048	86.6	134597	44658	37921	84.9

Table 2. Number of farmers participating in 1984 and 1985.

Zone	1984			1985[a]			1984–85		
	Expected	Actual	Performance (%)	Expected	Actual	Performance (%)	Expected	Actual	Performance (%)
Afam	20	60	300	20	26	130	40	86	215
Assa/Ibigwe	20	16	80	20	24	120	40	40	100
Egbema/Oguta	20	21	105	20	9	45	40	30	75
Imo River	20	27	135	20	24	120	40	51	128
Kolo Creek	—	—	—	20	29	145	20	29	145
Umuechem	20	12	60	20	14	70	40	26	65
Yorla	20	11	55	20	28	140	40	39	98
Overall	120	147	123	140	154	110	260	301	116

[a]Values apply to new farmers entering program.

and further multiplied for seed the following year, before the farmers could opt for ware yam production. Because of the limited supply of high-quality tubers, the program will reach only 20 farmers in each of the seven extension zones of the Division in the 5-year period. Participating farmers would serve as demonstrators and reference points for other farmers. It is intended that the benefits of the program would motivate unassisted farmers to start on their own seed yam production.

Program Outcome

The program has been implemented for 2 years (1984 and 1985) and the 3rd year has just begun. In 1984 and 1985, respectively, 83 294 and 134 597 setts were distributed, for a total of 217 891 yam setts. The recoveries in 1984 and 1985, respectively, were 86.6 and 84.9%, generating an annual average recovery of 85.7% (Table 1). The Afam and Umuecham zones achieved 108 and 109% recovery, respectively, because of the high yield obtained by the farmers and their honesty in declaring the true harvest to their cooperatives. The Imo River Zone realized 65.5% recovery because of the low yield associated with the low fertility of the soil and the unavailability of fertilizer in 1985. The Yorla Zone achieved only 58.4% recovery in 1985 because one group, who regarded the yams from the SCDP as a compensation for the oil being taken from their region, was unwilling to return the agreed proportion of the harvest. This group has been dropped from the program.

In 1984, 147 farmers participated in the program, representing 122.5% of the expected number (120). In 1985, 154 farmers participated; 140 were expected to participate (110.0% performance). Over both years, the average performance per zone was 116% (Table 2). The Afam, Imo River, and Kolo Creek zones reached performances of 215, 127.5, and 145%, respectively, because they were giving 500 setts or less to each farmer instead of the planned 1000 yam setts. The participants in these areas wanted the available yams to reach everyone, no matter the number of setts. This issue threatened the continued existence of the societies and the Extension Advisers had to yield to save the cooperatives. However, because the program was restricted

to cooperatives and the membership of the societies in Umuechem Zone is small, less than the planned number of farmers was reached in the 2-year period (65%). Likewise, the Egbema/Oguta Zone recorded a 75% performance because of less yam allocation as a result of the large inputs into this zone before the onset of the program.

Ugada Yam Extension Work

The socioeconomic study preceding SCDP activities in Ugada-Oguta of the Egbema/Oguta Zone revealed that the main occupation of the people in this region was yam production and that one of the major constraints was a lack of capital. The farmers were borrowing money and paying up to 150% interest. Another constraint was seed yam. Seed yams were traditionally bought from outside in the belief that the soil of the region was unsuitable for seed yam production.

Through SCDP extension service, the farmers were organized into a cooperative society with a loan from SCDP of NGN 48 000 for yam production in 1982 and 1983. This loan was refunded in 10 months instead of the agreed 12 months. SCDP extension staff linked the group with the United Bank for Africa (UBA) who, in 1984 and 1985, granted the society a loan of NGN 154 000 and members planted over 460 000 stands of ware yams. During the current season, this group, unassisted by SCDP, negotiated a loan of NGN 90 000 with the same bank. The capital constraint has thus been eliminated.

Regarding the production of seed yam at Ugada, SCDP extension staff set up a demonstration of seed yam production in the area from which a good yield was obtained. The people accepted that the yield was good, but asserted that if the seed yam were planted in soil of their region, a poor ware yam yield would result. Therefore, the staff set up a demonstration in their area. The yield was as good as that obtained from seed yams bought from the outside. As a result, over 162 farmers (66%) in the area now grow their own seed yam. Between 1984 and 1985, they planted a total of 125 300 stands of seed yam.

Impact on the Communities

The 5-year program, which is restricted to active participants, encouraged the formation of many cooperatives because farmers recognized them as promoters of increased agricultural production. Yam, whose production is popular with the people, is being restored along with the respectable social status it gives to those who produce and possess it. The program is popular with the people, gives substance to SCDP in the areas concerned, and generates good-will toward the Shell Petroleum Development Company. Sustained and dependable production has been assured because farmers now produce their own seed yams. Inhibitive traditions are disappearing. For example, wives in some areas no longer boil and eat small yam tubers passed to them after harvesting by their husbands, according to tradition. Small tubers are not planted to produce seed yams. Furthermore, in one region, the tradition of buying seed from outside has been broken. In another area, the farmers now work out their seed requirements and sell the surplus during the planting period when the price is high instead of waiting until they finish their own planting by which time the demand (and price) has dropped.

Problems

Tuber preservation and storage are major problems. From preliminary trials, it appears that storing in a house gives better results than storing in an open barn and that heavy shading of the barn is deleterious. This aspect of the program requires research assistance and support. Insufficient planting material and nemotodes are also problems. Carbofuran, which helps in nematode control, is sometimes unavailable; when it is available, however, the cost is too high for the farmers. Effective research on nematode control considering cultural practices is required.

In the 5-year program, getting the farmers to further multiply their harvest share for another year before starting ware yam production is a problem. The farmers want to produce ware yams after 1 year. We are not likely to yield to pressures in this regard because the ownership of sufficient seed is cardinal to the objective of the program. We have begun to eliminate from the program those farmers who are unwilling to multiply the material and who default in returning the agreed quantity of harvest.

Because of illiteracy among farmers, records separating their personal plantings from the materials supplied by SCDP are not kept. Consequently, it is difficult to monitor and evaluate the growth of the farmer when he ceases to receive setts from SCDP. Tradition and custom are also sometimes detrimental. In some communities, deaths during the critical yam-planting season require that farmers abstain from farm work for over 4 days in sympathy and respect. This leads to delayed planting, poor harvest, and a low return to SCDPs. Finally, the unavailability of fertilizer at the crucial time, particularly in areas with poor soil, is a serious problem.

Future Plans

Shell plans to fully execute the 5-year program and reach the 700 farmers targeted. To accomplish this and have enough materials, minisetts instead of macrosetts should be distributed. This approach however, may not produce the size of seed yams needed in some areas in one generation. (Demonstrations of seed yam production by the minisett technique have been set up at our Bori farm and also at the Agbarho multiplication centre in the Company's Western Division, where the yam extension work is starting.) Recovery efforts will be intensified. We shall continue to restrict the program to cooperatives because they have contributed to the success realized. Their action committees distribute the yams received from Shell, inspect the crop in cooperators' farms, and recover the agreed proportions of the harvest. Where all the members in an existing cooperative have benefited and difficult entry conditions are being given to prospective members, we shall organize a new society in the community so that the yam can reach more people. Efforts will be directed toward obtaining the planting records of people who stopped receiving yams from Shell to examine their growth. Farmers who attain the 5000-stand planting stage will be assisted to get bank loans to further expand production on a commercial scale. Four farmers in Egbema area have reached this stage.

Conclusion

For 9 years, Shell has been involved in yam extension work in its Eastern Division. During this period, a 5-year program was designed. The program is currently in its 3rd year and, so far, has been successful. Shell intends to monitor, evaluate, and organize the program so that it becomes a model to other interested agencies.

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CASSAVA PRODUCTION IN RWANDA: STATE OF THE ART

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Cassava plays an important role as a carbohydrate source and food resource in Rwanda. It fits well into the farming system and tolerates various environmental stresses. Our survey of cassava production in Rwanda provided an insight into production practices and the limitations of the existing genetic pool. The establishment of a multiplication system for the supply of healthy planting material is recommended.

Cassava plays a very important role as a basic dietary carbohydrate source in Rwanda, as in many African countries. Rwanda has one of the highest population densities in Africa and a very intensive agricultural system. Cassava is cultivated in areas ranging from dry marginal lowlands to altitudes of 2100 m above sea level (asl). Because of the ability of cassava to sustain yields during the long dry season and in marginal soils, its cultivation is increasing (Kamanzi 1983; Delepierre 1985; Rwamasirabo 1985). Consequently, cassava is important as a cash crop.

Despite the growing importance of this crop, the increasing awareness of consumers about cassava quality, and information on its distribution, clones most commonly grown and preferred at the farm level are not available. Consequently, a survey was initiated to improve our knowledge of cassava production in Rwanda and to identify the aspirations of cassava farmers.

SURVEY METHODS

This questionnaire survey collected qualitative and quantitative characteristics of the field and cultural practices of 57 farmers from seven major cassava-producing regions in Rwanda. In each region, three farmers from each of three communes were sampled. On each farm, a minimum of three team members interviewed farmers about their cassava plots. The survey covered relative size of cassava fields, clones used, methods of planting, times of planting and harvesting, storage, processing, marketing, and consumption patterns and preferences. Percent frequency distributions were used to analyze the data.

RESULTS

REGIONS

Cassava is grown in agricultural regions of Rwanda ranging in altitude from 1000 to 2100 m asl (Table 1). The seven main cassava-growing areas in these regions had a mean altitude of 1477 m asl, with 69% of the farmers at 1400–1650 m, 15% below 1400 m, and 16% above 1650 m.

LAND PREPARATION AND PLANTING

Cassava plots, which range from less than 0.05 to 1.5 ha and have a mean size of 0.22 ha, are all prepared by hoe. Plots are usually plowed flats; ridges are rarely used. About 13% of cassava land was previously under long-term fallow; 17% was under short-term fallow (one or two seasons). The

Table 1. Altitude (m above sea level) of the major cassava-growing regions of Rwanda.

Region	Altitude[a]
Imbo	1116 (1000–1400)
Impala	1456 (1450–1500)
Central Plateau (granitic ridge)	1850 (1750–2100)
Mayaga	1505 (1450–1650)
Bugesera	1405 (1350–1450)
Eastern Plateau	1524 (1450–1700)
Eastern Savanna	1438 (1300–1600)

[a]Values are means with the range in parentheses.

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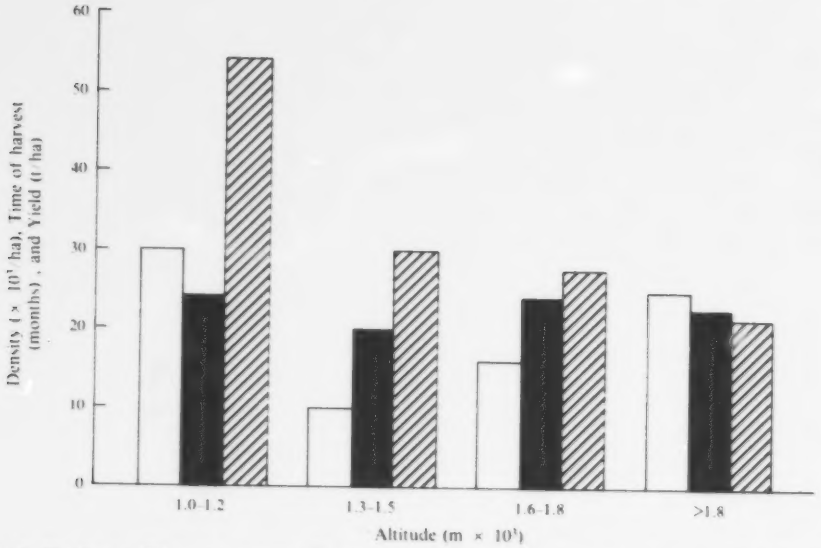

Fig. 1. *The density (□), time of harvest (■), and mean yield (▨) of cassava at different altitudes in Rwanda.*

remaining 70% of plantings followed other crops: beans, sweet potato, and sorghum accounting for 47%.

About 86% of farmers planted cassava in both the first (September–October) and the second (May–June) seasons. During the first season of 1984, about 65% of Rwandese farmers grew cassava (Rwamasirabo 1985). The second season planting time is influenced by labour availability and, at this time, other crops usually get higher priority for labour.

About 85% of the farmers surveyed obtained planting materials from their previous crop. This material was usually of poor quality because it included uncleaned, mosaic-diseased stems of improper physiological age. Other sources of limited planting material include the Institut des sciences agronomiques du Rwanda (ISAR), the national seed service, and other agricultural projects.

The stem is cut into 10–30 cm long segments and planted horizontally or vertically at various spacings depending on whether it is mixed or sole cropping. Plant densities range from 1 000 to 40 000 plants/ha, with a median density of 14 000 plants/ha. Neither fertilizer nor compost are applied to cassava.

Varieties and Cropping Systems

From the seven regions, a total of 20 varieties were found. Of these 20, 6 were bitter varieties grown by 54% of the farmers, of which cv. Eala 07 covers about 40% of the cassava-growing area. The 14 sweet cassava varieties were grown by 46% of the farmers, and cv. Gacyacyali alone accounted for up to 70% of the sweet cassava grown in the dry areas. In all, farmers each grow an average of three varieties, including both bitter and sweet types.

About 67% of farmers surveyed grew cassava in association with other crops: beans, 32%; peanuts, 20%; sweet potato, 15%; maize, 12%; sorghum, 10%. Other special associations are with banana, cocoyam (*Xanthosoma*), and other vegetables (Kamanzi 1983; and Price 1984).

Harvesting

Harvesting is usually done by hoe or manual uprooting. A small percentage of farmers will occasionally harvest only a few tubers from a stand (milking), although 72% of farmers harvest over 8–12 months for sweet cassava and 12–48 months for bitter varieties, with the bulk occurring during the long dry season.

The median cassava yield in this survey was 2.7 kg/m², with a range of 0.8–6 kg/m² that was greatly influenced by the time and altitude of harvesting (Fig. 1). The yield of roots (y, tonnes per hectare) declined with increasing altitudes (x, metres): $y = 97.8 - 0.041\,x$.

Processing (Bitter Cassava)

Cassava-based diets are mainly detoxified by fermentation techniques. Fermentation may be wet or dry, and 91% of farmers surveyed ferment cassava in

water; only 9% use dry fermentation.

In wet fermentation, harvested cassava is either peeled, washed, and soaked in water, or soaked in water, fermented, peeled, and washed. The soaking (fermentation) usually lasts 4–7 days.

Dry fermentation is usually practiced in areas with severe water shortages and involves smaller quantities of cassava. Similarly, the cassava roots are peeled, left whole or cut into pieces, placed in a basket lined with banana leaves, which may or may not be sprinkled with water and then covered with more leaves, and allowed to grow mouldy for 4–6 days. The moulds are removed after fermentation and the mash is dried.

Drying is done on raised platforms, floors, and rooftops for 1–18 days depending on weather conditions; under normal conditions, drying is completed in 4–7 days. Dried cassava chips are stored in baskets or bags, or ground into food flour using a grinding mill or mortar.

Many consumers base their selection of cassava chips and cassava flour mainly on colour: brown being inferior to white, although their prices are the same.

Where grinding mills are available, they operate daily at a fee of RWF 2/kg chips (in February 1987, 81 Rwanda francs [RWF] = 1 United States dollar [USD]). Many mills are located in urban areas and, at peak operation, mill 3–5 t/day, thus offering a very important and efficient service to farmers.

Marketing

Farmers grow cassava mainly as an important and reliable source of food during times of food shortage (usually during the long dry seasons), but also for cash. About 71% of growers sell more than 45% of their output.

In the marketing of cassava chips from producers to urban consumers, the producers bring their product, mainly dried chips, in baskets on their head to the local markets, which meet once or twice weekly in a given area. Dealers and traders bring trucks from the cities to these markets and buy large quantities for resale at intermediary centres, which can store up to 15 t, or in the cities. Of the retail market, Kigali holds 60%; Kamembe, 14%; Butare, 9%; and other markets, 17%.

Prices are cheapest at the local markets and, depending on the area and the season, a basket of cassava chips (15–20 kg) sells for RWF 200–500 and is retailed at RWF 7–30/kg. In the cities, chips are retailed at RWF 25–30/kg. Chips are ground at mills for RWF 2/kg and the flour is sold for RWF 40–50/kg. Most consumers mill 10–20 kg chips per visit.

Table 2. Frequency (%) of cassava consumption in two regions (R1 and R2) of Rwanda.[a]

Times per week	Cassava flour as pâté or gari		Fresh tubers	
	R1	R2	R1	R2
1	—	50	37	—
2	28	37	50	25
3	37	—	—	31
4	13	—	—	19
5	10	—	—	—
6	12	13	13	—
7	—	—	—	25

[a]See text for descriptions of R1 and R2.

Consumption Pattern

Fresh, sweet cassava and processed, bitter cassava consumption in Rwanda is widespread and contributes about 8% of the total food energy intake of adults and children. The frequency of consumption varies with the region and the season, but per capita consumption is similar across regions. Cassava is usually eaten with beans, meat, fish, peanuts, or vegetables. During the dry season, fresh cassava may be eaten alone after boiling. Raw sweet cassava is sometimes eaten in small quantities by children as a snack.

In a medium to high altitude cassava-growing area (region 1, R1), most families eat cassava flour as gari or pâté 2–6 times/week, with a mean of 3 times/week (Table 2). Their fresh cassava consumption is less frequent, generally 1 or 2 times/week. In region 2 (R2), which is a drier area, most families eat cassava flour less frequently, generally 1 or 2 times/week (Table 2). In this region, fresh cassava is more frequently consumed (5 times/week). This was also observed by D.S. Ngambeki, who reported a fresh cassava consumption rate of about 4 times/week (personal communication). Although a survey was not done in the capital city of Kigali, cursory observations show that there is a high frequency of cassava consumption. Some families eat cassava every day and the grinding mills in the populated parts of Kigali are always busy.

Cassava Constraints

Low Yield Potential

Many local sweet cassava clones grown by the farmers are late bulking and low yielding after 9–12 months. Survival and growth during the long dry seasons result in severe dieback and late recovery. Although cassava is increasingly being planted at high altitudes (1650–1800 m), these clones are not

adapted to such environments and consequently give low yields, even after 24 months. The most widespread bitter variety produces good yields if it is planted with healthy stems.

Diseases and Pests

The most serious pest of cassava in Rwanda is the cassava green mite (*Mononychellus tanajoa*). This pest occurs in about 70% of the cassava-growing area and possibly causes crop defoliation during the dry season. Recently, the cassava mealybug has been found in an area with minimal cassava growth; nevertheless, this pest now threatens cassava production in Rwanda. Cassava mosaic disease is widespread in farmers' fields and is frequently spread via planting material used by farmers. Severe cassava bacterial blight is localized to areas at intermediate altitudes with poor soils. *Cercospora* leaf spot causes severe leaf fall during the rainy season. Together, cassava mosaic disease, cassava bacterial blight, and *Cercospora* leaf spot account for 70% of cassava disease problems in Rwanda.

Constraints of Utilization

Although the production and utilization of cassava as human food is increasing, an improvement of utilization is needed. Processing requires a much higher labour input compared with other common food crops. In some areas, processing hygiene also requires improvement. Eating habits limit the diversity of food forms. For example, using composite flours with sorghum, which increases the biological value of cassava diets (particularly for young children) or using cassava leaf as a nutritious vegetable is rare.

Conclusions

This survey showed that cassava fits well into prevailing farming systems, which use limited production inputs, and, increasingly, is a preferred food for meeting the food energy needs of many farmers in the drier regions of Rwanda. Cassava is able to adapt to late planting and weeding, which are favourable to the farmer, can remain in the field and be harvested as needed, and stores well after processing. The most important role of cassava is as a farm household food security crop, especially during extended dry seasons.

Although several cultivars are grown by farmers, there are obvious varietal limitations. One variety alone accounts for over 40% of the bitter cassava produced and, for sweet cassava, one variety can account for up to 70% in any given area. This pattern greatly enhances the possibility of serious diseases and pest epidemics, which now threaten cassava cultivation in Rwanda because of the presence of the cassava mealybug. Furthermore, 1 or 2 varieties cannot optimally exploit the available agroecologies of the country. Thus, to increase yields and check genetic vulnerability, new disease- and pest-resistant varieties that are adapted to the major cassava-growing areas must be developed. To sustain high yields in the short run, multiplication and distribution of healthy planting materials from available recommended varieties is necessary.

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